Title: Emotional contagion in dogs as measured by change in cognitive task performance

Abstract: Domestic dogs are living with humans in a very special inter-species relationship. Previous studies have shown physiological and hormonal synchronisation between dogs and their owners during positive interaction. Dogs are also known to be able to discriminate human emotions and they were also presupposed to have the capacity to empathise with humans. Based on these results we hypothesize that the owner's emotions can be contagious to the dog and stress-related emotional changes in dogs can be tracked by memory tasks because both human and nonhuman studies indicate a significant effect of perceived stress on subjects' cognitive performance. In the present study the owners, after having completed State Anxiety Inventory and having participated in a memory task, were manipulated with either negative (Stressed owner condition) or positive (Non-stressed owner condition) verbal feedback in an additional task. Results indicate that the owners' self-reported anxiety significantly increased in the Stressed owner condition due to the manipulation. We also measured the effect of the different manipulations on the owners' and also on their dogs' memory performance and found that in line with earlier studies the stress-evoking intervention had an improving effect on the owners' memory performance. After separation from their owner (Stressed dog condition) dogs also showed better performance in a spatial working memory task and, more interestingly, task completion was also affected by the manipulation of their owners stress level. These findings provide further support for the emotional contagion between dogs and their owners, and suggest that measuring changes in the memory performance can be used as an indicator of contagion-induced changes in dogs' stress level.
Dear Dr Per Jensen,

we are hereby resubmitting our manuscript entitled „Emotional contagion in dogs as measured by change in cognitive task performance”. We would like to thank you for the positive response and for the opportunity of resubmission. We would also like to thank the reviewers for their thorough attention and for the suggestions they made in order to improve the manuscript. We hope you will find that we have addressed all the concerns raised. Below we provide detailed answers to the comments.

Yours sincerely,
Zsófia Sümegi

**Comments made by reviewer 1:**

1. Overall this manuscript is well written, but could use further editing for punctuation and grammar

We carefully re-read the manuscript and hopefully made improvements compared to the previous version with respect to grammar and punctuation.

2. Use of the terms stress, stressed, and distress in the current manuscript are quite loose, and sometimes seem to be based more on colloquial definitions rather than scientific definitions. Given that the human testing instrument that was used assessed anxiety, it might be more appropriate to change the terminology to reflect the actual manipulations.

Thank you for bringing our attention to the inconsistency. We changed the term „stress” to „anxiety” when describing the affective state of the owner. However, we decided to use the term „stressed” in other cases (see – for example – the condition names) as our aim was to apply a moderate stressor (negative feedback on performance) on participants. Since we cannot be sure whether the dogs actually experience „anxiety”, „distress” or something else, we decided to keep the term „Stressed” (describing the nature of the manipulation).

3. P9 L194: Since the owners knew where the ball was, were they instructed not to direct the dog towards the correct pot while encouraging them? Is it possible that their behaviour (aside...
from general level of encouragement) may have introduced bias that influenced the canine results?

Owners were specifically instructed not to direct the dogs’ behaviour in any specific way. We added a clarification sentence about this to the manuscript (P9 L213-215).

4, P11 L241-3: Please clarify - do you mean that there were the two possible trial orders described for phase 1, and they received one of them in phase 1 and the other in phase 3?

Yes, this is described in the section about Phase 1. In the new version of the manuscript, we refer back to that in order to make this part easier to follow (P11 L265-266).

5, P11 L259: What happened if the dog did show 20s of distress? Were they immediately reunited with their owner?

They were immediately reunited with their owners. We added a sentence to this part of the manuscript to clarify (P12 L282-284).

6, P12 L278-9: Was this calculated as the number of wrong choice for each trial, or for all 5 trials?

It was summarized for all 5 trials. See P13 L304.

7, P19 L443-4: What exactly is meant by inner state? Maybe affective state would be more appropriate here then inner state?

We agree that affective state is a more appropriate term and made these changes throughout the manuscript.

8, P20 L473-82: Given your inclusion of this discussion on the baseline memory values in the manuscript, it would be helpful to include the pre/post data in the figures rather than just the change.
We added a figure about the pre- and post manipulation data about the memory performance of the owners (Figure 3).

9. Figures: Change ",," to "." for number, or remove significant digits because they are unnecessary for the legend (e.g., 20 versus 20.00)

We made the changes in the figures, thank you for bringing our attention to this.

**Comments made by Reviewer 2:**

1. **Highlights:**
   
   3 Dog's stress level can be influenced via the owner in an artificial situation. There is no direct evidence about this in the paper - only dogs' working memory was measured in the experimental condition.

   We agree that only indirect evidence supports this idea, thus we have removed this sentence in the revised manuscript.

2. **Introduction** - It is a well-written section, however perhaps a little bit too condensed.
   
   Line 69-72: "the relationship between the dog... emotional responsiveness": there is now evidence for the presence of a correlation between the owners' attachment profile and the owner-dog attachment bond, the following reference should be added at this point and discussed also in the light of the main topic of the paper (i.e. emotional heterospecific contagion): Siniscalchi M, Stipo C, Quaranta A (2013) "Like Owner, Like Dog": Correlation between the Owner's Attachment Profile and the Owner-Dog Bond. PLoS ONE 8(10).

   Thank you for bringing our attention to this relevant paper. We incorporated the reference into the introduction and mentioned its relevance to heterospecific assimilation (P4 L79-84).

3. **Subjects** - The authors should inform the reader about the level of training/obedience of their subjects. There can be considerable differences in the experience and performance quality among dogs during tasks (both spatial memory task phase 1-3 and human dog collaborative task- phase 2) based on their age, breeds and the level they already performed.
We agree that dogs’ behaviour in heterospecific interactions may differ considerably based on their level of training, although we had no specific predictions in regards of emotion contagion as the susceptibility to such phenomena is probably due to evolutionary processes and not experience. However, we admit that there may be other views or stances on the subject and therefore, we completely agree that the inclusion of data and analyses about training level is necessary. Out of the 54 dog participants, 33 had taken part in some sort of training; however they were approximately evenly distributed across conditions. See the „Subjects” section (P7 L161-166).

4. Line 181- "Right after their arrival the owners filled out the Hungarian version of the State- and Trait Anxiety Inventory (STAI; Sipos & Sipos 1983) which is widely used by psychologists to measure the anxiety both at a particular point in time (state) and in general (trait)”: I would like to know why the authors did not use also more objective tools for measure the anxiety (e.g. wireless heart rate monitor devices which are very reliable and easy to use). I recommend that the authors conduct tests with this in mind in future.

Thank you for your suggestion, we agree that such devices can be of great use in studies like our and we will keep this in mind when conducting similar studies in the future. However, we believe that the questionnaire we used is also appropriate for these purposes and this is supported by the fact that it is a widely-used and standardized tool to measure anxiety.

5. Line 220-226- "This was followed by interactive situations, when owners were asked to complete different kinds of collaborative tasks together with their dogs. First a ball-carrying task during... and they also had the opportunity to show other tricks": the level of anxiety/moderate stress during this Phase could be due to the different degree of subjects' training (e.g. general obedience); if this aspect is impossible to analyse, it should be at least mentioned and discussed

Thank you for pointing out this possibility. We added some analyses about the effect of training on dogs’ memory performances and the results were always non-significant (before-after manipulation and level of change). Also, we incorporated training level as a covariate into the main analysis. If dogs responded differently to the manipulation according to their level of training, we would have expected to see some effects manifested here. Also, the distribution of trained dogs did not differ significantly across conditions; therefore training
level is unlikely to account for our results. We added a section to the Results (P20 L464-469) as well as to the Discussion (P22 L515-521).

6, Data collection - Line 277 -282: "Dog's working memory performance was calculated... and post-manipulation measures". No data are available about the time required to solve the task (which could be important for the motivation of the subjects) and neither about the number of attempts required to complete the task (do all dogs complete the tasks? was there a time limit to complete the task?).

Our main variable was the number of attempts required to complete the task (see P13 L302-307). There was no time limit, dogs had as much time as they needed (P 10 L218) and this way, all dogs completed the task (duration ranged between 4.9 – 10.6 minutes).

7, Line 295 - "stressed dog" control: see above (comments - line 181) about the possibility to use a wireless heart rate monitor device to measure stress response also in dogs.

We agree in principle with the reviewer that such devices can be useful and may provide a more precise estimate of treatment effect. However, evidence indicates that individual stress response is difficult to measure in dogs based on heart rate, because it is significantly influenced by activity level and body position (see Maros et al. 2008 Appl. Anim. Behav. Sci109 329–341).

8, Why authors did not recorded dogs' behavior also during Phase 2 of the experimental conditions? This could provide direct evidence that "the stress experienced by the owner is contagious to their dogs..."

We considered this possibility but came to the conclusion that coding the behaviour of the dogs in this phase would result in data that do not reflect the affective state of the dog. Since this is an interactive phase, the behaviour of the dog is merely a reaction to the owner and therefore it tells us more about the actions of the owner than the inner state of the dog. For example, an owner in the Non-stressed condition would supposedly be more willing to play with the dog and as a response the dog would probably also show more signs of playfulness. However, whether the behaviour results from the stimulation or from a positive affective state is impossible to disentangle in this case.
9, Line 307-313. "Crucially, the coder did not speak the language that was used throughout the experiment; therefore he could not understand the content of the communication".

This is true, but what about dogs? The ball-carrying and obedience tasks were also accompanied by the experimenter's negative or positive feedback: I mean that dogs could pick up the meaning of very simple word like "good", "wrong", "right" even in the absence of other non-linguistic cues.

We applied this method of coding because a person who does not speak the language can basically rely on the same cues as a dog: voice pitch, facial expression and other non-verbal gestures. Therefore the coder could pick up on all the cues that were available for the dogs as well – and probably could do it even more easily. It is true that the experimenter provided feedback about the performance during the ball-carrying task as well, however we believe that it is highly unlikely that dogs could be affected by that for two reasons: first, the feedback was not given to the owner in the form of command words, but in full and complex sentences. Therefore, it would be very hard for dogs to infer the meaning of these utterances especially considering the scarcity of evidence about dogs’ ability to understand human verbal communication (see Bloom, 2004 Science, 304,1605-1606). Second, it has been shown that dogs are more likely to pay attention to communication that is directed to them as opposed to a third party – in this case the owner (e.g. Virányi et al. 2004 Behav.Proc. 66, 161-172). Taken all these together, we believe that there is reason to state that the dog’s affective state was not directly influenced by the experimenter.

10, Results lines 412-416: "dogs in both Stressed owner and Stressed dog conditions showed a significant improvement in the post-manipulation (Phase 3) working memory test... In the Non-stressed owner condition, however, there was no change". Once again: dogs' training habits cannot be disregarded.

We included some analyses on the effects of training levels (see above).

11, Line 483: "A key finding of the present study is that the stress experienced by the owner is contagious to their dogs and that these effects are ALSO transferred to the cognitive domain." line 509: "In sum, we showed the SAME effect in dogs as in their owners with direct manipulation of the owners only, supporting the existence of the emotional contagion between
two different species" and line 518: "moreover the owner's inner state seems to be contagious to the dog, so it is possible to influence the DOG’S STRESS LEVELS! via the owner even in an artificial situation.

There are no direct measures/evidences about dogs’ stress in the two experimental conditions.

We agree, however we believe that our study provides indirect evidence of the owner’s affective state influencing that of the dog and therefore such conclusions are valid. Nonetheless, we understand the concerns and rephrased some parts of the discussions (P22 L522-528; P23 L562-563). We hope that this version eliminates the possibility of drawing far-fetched conclusions.
Research highlights

1 Stress has an improving effect on the humans’ and dogs’ memory performance.

2 Dogs’ memory performance can be affected by their owners’ stress level.

3 Our results support for the emotional contagion between dogs and their owners.
Emotional contagion in dogs as measured by change in cognitive task performance.

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Abstract

Domestic dogs are living with humans in a very special inter-species relationship. Previous studies have shown physiological and hormonal synchronisation between dogs and their owners during positive interaction. Dogs are also known to be able to discriminate human emotions and they were also presupposed to have the capacity to empathise with humans. Based on these results we hypothesize that the owner’s emotions can be contagious to the dog and stress-related emotional changes in dogs can be tracked by memory tasks because both human and nonhuman studies indicate a significant effect of perceived stress on subjects’ cognitive performance. In the present study the owners, after having completed State Anxiety Inventory and having participated in a memory task, were manipulated with either negative (Stressed owner condition) or positive (Non-stressed owner condition) verbal feedback in an additional task. Results indicate that the owners’ self-reported distress anxiety—significantly
increased in the *Stressed owner* condition due to the manipulation. We also measured the
effect of the different manipulations on the owners’ and also on their dogs’ memory
performance and found that in line with earlier studies the stress-evoking intervention had an
improving effect on the owners’ memory performance. After having separated from their
owner (*Stressed dog* condition) dogs also showed better performance in a spatial working
memory task and, more interestingly, task completion was also affected by the manipulation
of their owners stress level. These findings provide further support for the emotional
contagion between dogs and their owners, and suggest that measuring changes in the memory
performance can be used as an indicator of contagion-induced changes in dogs’ stress level.

keywords: emotional contagion, dog-owner relationship, stress, memory

**Research highlights**

1 Stress has an improving effect on the humans’ and dogs’ memory performance.

2 Dogs’ memory performance can be affected by their owners’ stress level.

3 Dog’s stress level can be influenced via the owner in an artificial situation.

3 Our results support for the emotional contagion between dogs and their owners.
1. Introduction

Emotional contagion, a concept coined by Hatfield et al (1992) can be described as an automatic response to perceiving another’s emotional state through which a similar emotional response is triggered in the observer. The phenomenon can be seen as a primitive form of empathy which appears to be widespread amongst mammals. However it is widely accepted that the contagion of emotional responses does not require the ability to differentiate between own and other’s emotions or any conscious control over emotional reactivity (Preston & de Waal 2002).

Emotional contagion has been extensively examined in rodents (for a review see Edgar et al. 2012). For example social transmission of fear response has been reported in rats (Knapska et al. 2010) and pain sensitivity in mice also seems to be influenced by a conspecific’s pain response (Langford et al. 2006, Jeon et al. 2010). Birds may also show evidence of emotional contagion, greylag geese (Wascher et al. 2008) as well as chickens (Edgar et al 2011) show physiological responses while observing distressed conspecifics. Regarding the empathic abilities of nonhuman primates there is evidence for contagious yawning in both apes (chimpanzees - Anderson et al. 2004) and monkeys (macaques - Paukner & Anderson 2006) and rapid facial reactions to the partner’s emotional facial expression during play has been described in orangutans (facial mimicry - Ross et al. 2008).

There is ample evidence that empathic-like responding is usually more pronounced between familiar conspecifics than unfamiliar peers (e.g. Langford et al. 2006, Ben-Ami Bartal et al. 2011, Ma et al. 2011), importantly, however, contagious behaviour can occur also in heterospecific contexts. A recent study provides support for the notion of cross-species contagious yawning in chimpanzees (Madsen et al. 2013) and there is ample evidence suggesting emotionally connected heterospecific yawn contagion in dogs (Joly-Maschonni et al. 2008, Silva et al. 2012, Romero et al. 2013).
Human-dog cross-species contagious yawning has a potential link with the specific social-cognitive capacities of the domestic dog (Yoon & Tennie 2010). In fact, many assume that dogs are socially tuned-in to humans because as a result of their unique domestication process, they have developed an evolutionary novel, inter-specific type of social competence. The result of their unique domestication process was the emergence of an evolutionary novel, inter-specific type of social competence which, among others, allowed for the establishment of a wide range of affiliative social relationships with humans (Miklósi & Topál 2013). The relationship between the dog and its owner is functionally similar to the mother-infant attachment (see Topál & Gácsi 2012 for a review) which is considered essential for the development of dogs’ emotional responsiveness (Plutchik 1987). Moreover, a recent study has found a correlation between the owner’s attachment profile and the quality of the dog-owner attachment bond (Siniscalchi et al., 2013). In addition to providing further support for the notion that the dog-owner relationship resembles the connection between a mother and her child, these results also support the idea that dogs tend to assimilate the characteristics of their owners and this is manifested in their affective stance.

Moreover dogs and children tend to correspond in the degree to which they are able to react to the challenges of human communication (see Topál et al. 2014 in press, for a review). They possess enhanced skills in reading human visual attention (e.g. Kaminski et al. 2009) and show special responsiveness to human gestural communication (e.g. Lakatos et al. 2012). Dogs can also learn to discriminate between different human emotional expressions (Deputte & Doll 2011, Nagasawa et al. 2011; Racca et al. 2012) and respond differently to commands given with emotionally different tones of voice (Ruffman & Morris-Trainor 2011). They are not only sensitive to the emotional state of their owners (Morisaki et al. 2009), but their behaviour can even be influenced by the owner’s emotional expression (Merola et al. 2012).
Dogs’ interspecific social- and emotional responsiveness is further supported by recent investigations (Silva & Sousa 2011, Romero et al. 2013) that raised the possibility that dogs have the ability to feel humans’ emotional experiences (‘affective empathy’). It is worth mentioning, that unlike the cognitive empathy system which entails representing another’s emotional experience (deWaal 2008), affective empathy, is often described as an ‘automatic’ process (Hatfield et al. 1993) stemming from an unconscious social contagion system. That is, instead of being able to represent another’s emotional experience (cognitive empathy) dogs may have affective responses to the observed emotion of the human (i.e. feel what the human feels).

Social contagion can be seen as the rudimentary mechanism that serves to synchronize partners at different levels (physiological, emotional and behavioural synchronization). There is some experimental evidence suggesting hormonal and physiological synchronisation between owners and their pet dogs. Affiliative interactions between dogs and humans can have stress relieving effects; lower cortisol level as well as increased oxytocin and dopamine levels in both species (Odendaal & Meintjes 2003, Miller et al. 2009, Handlin et al. 2012). Hormonal interactions between people and dogs may also occur under conditions of psychological stress (e.g. after losing a competition - Wirth et al. 2006). For example, Jones and Josephs (2006) investigated the hormonal changes in dog-human teams during agility competition and found that in losing teams, unlike in winning ones, the owners’ pre-competition basal testosterone levels and their pre- to post-competition changes in testosterone are significant predictors of dogs’ changes in cortisol level.

In addition to direct measurement of hormonal changes, the effects of stress on subjects’ internal state can also be assessed indirectly; either by using questionnaires (e.g. Frankenhaeuser et al. 1978) or by measuring changes in subjects’ cognitive performance. Some studies suggest that stress hormones can have an inverted-U shape effect on learning
and memory in both humans and nonhuman animals (McEwen & Sapolsky 1995; Belanoff et al. 2001). While moderate stress has been shown to positively impact memory retention, high stress levels can lead to impaired cognitive performance.

Although findings suggest that dogs show high responsiveness to changes in their human caregiver’s stress status, and there is also evidence that stress-related emotional changes can be tracked by memory tasks, investigation of the association between stress-induced changes in owners and their dogs as measured by changes in their memory performance is lacking in the literature.

In the current study we investigated whether pet dogs can take over the emotional state of their owners in the context of experimentally induced anxiety and whether changes in their owners’ affective states have an effect on dogs’ memory performance. Owners’ anxiety levels were experimentally manipulated: they were told that they were participating in a task designed to measure one aspect of their cognitive performance, a ‘word list memory task’ (WMT). Owners were assigned either to the Non-stressed or the Stressed condition in which the difficulty of the task and the amount of experimenter-delivered positive/negative verbal feedback were surreptitiously manipulated. We predicted that (I) our procedure should be sufficient to increase the owners’ self-reported stress/anxiety in the ‘stressed’ condition; (II) these changes should have an effect on owners’ memory performance in the WMT and (III) the changes in owners’ affective states should be contagious to dogs and the emotional contagion should be manifested in changes in the dogs’ memory performance. As a control, we also ran a condition in which the dog’s stress level was directly manipulated (Stressed dog condition) as opposed to being indirectly affected through the emotional state of the owner. This allowed us to test whether the potential change in cognitive performance following an indirect manipulation is comparable to that in case of more direct effects. We used the ‘separation paradigm’ because ample evidence suggests that separation from the owner in
unfamiliar environments evokes moderate stress and anxiety in dogs (see Topál & Gácsi 2012 for a review).

2. Materials and Methods

2.1. Subjects

52 dogs (mean age ±SD: 3.81±1.82 years, 26 males and 26 females) participated in the study on a voluntary basis. Out of the 52 dogs, 37 were tested together with their owners (experimental conditions; owners’ mean age ±SD: 30.5±8.4 years, 34 women and 3 men) Subjects were randomly assigned to one of the following three conditions: Stressed owner (n=19), Non-stressed owner (n=18), Stressed dog (n=15). In the subsequent sections, we refer to the first two conditions as "experimental" and to the third one as "control". The dogs were from 18 different breeds (8 Golden retrievers, 5 Border collies, 3-3 Fox terriers, Hungarian vizslas, Labrador retrievers, 2-2 Collies, West highland terriers, 1-1 Boxer, Chihuahua, Dalmatian, Havanese, Jack Russel terrier, German shepherd, Schipperke, Yorkshire terrier, Poodle, Rottweiler, Shiba Inu) and 15 mongrels. Dogs’ previous training experience was also assessed. Out of all the participants, 33 dogs had received some sort of obedience training, while 19 had never participated in any formal training. However, the distribution of “trained” and “untrained” dogs did not differ significantly across conditions, with 13, 12 and 8 trained dogs in the Stressed-owner, Non-stressed owner and Stressed dog conditions, respectively ($\chi^2(2)=1.25; p=0.53$)

2.2. Experimental arrangement
The experiment took place in a room (3.9 m x 4.1 m) at the Dept. of Ethology, Eötvös University, Budapest. Only a chair and some toys (a tennis ball and a rope) for the dog were placed in the room. These toys were present during the whole experiment, except for the dog memory tasks (see below) when only one ball as target object and 7 plastic flowerpots as hiding places were used. However in the ball-carrying task (Phase 2 – see below) and during the second dog memory task (Phase 3 – see below) additional balls (2-3) and containers (2) were also present.

2.3. Overview of the experimental procedure

The procedure consisted of three phases for both the experimental and the control conditions. In the experimental conditions the pre-manipulation phase (Phase 1) started by assessing the owners’ baseline anxiety level (using a state anxiety questionnaire) and their memory performance (in a word list memory task) and we also measured the dogs’ ability to retain the location of a ball in their working memory (in an object hiding and finding tasks). In the control condition, only the dog memory task was administered in phase 1. This was followed by the manipulation (Phase 2) during which the owners in the experimental conditions had to answer questions about an article they had read before and they were also asked to complete collaborative tasks together with their dogs. The latter part was added to the procedure to enable the transfer of stress/anxiety between the human and his/her dog. Importantly, owners in the Stressed owner condition received mostly negative feedback, while owners in the Non-stressed owner condition were given only positive feedback. In the Stressed dog condition, the dog’s anxiety level was manipulated by introducing a short period of separation from the owner. Finally, in the test phase (Phase 3), the owners’ and their dogs’ memory performances as well as the owners’ state anxiety were re-tested using the same
methods as used in Phase 1. In the control condition, only dogs’ memory performance was assessed.

2.4. Procedure of the experimental conditions (Stressed owner and Non-stressed owner)

2.4.1. Phase 1 – Baseline measures

Right after their arrival, the owners filled out the Hungarian version of the State- and Trait Anxiety Inventory (STAI; Sipos & Sipos 1983) which is widely used by psychologists to measure the anxiety both at a particular point in time (state) and in general (trait).

After this the owner and his/her dog were led into the experimental room by the Experimenter (E) and were allowed to explore the room for a few minutes. Then the owner made the dog sit at a predetermined starting point and the E placed seven identical brown plastic flowerpots (11 cm high, 14 cm in diameter) on the floor in a semicircle (Figure 1). The dog was sitting equidistant from the bowls (3 meters away) while being held by the owner. The E then took the target object (a tennis ball), showed it to the dog, walked straight towards one hiding location, and placed the ball into the pot clearly visibly to the dog. After the hiding event the dog was led out of the room by the owner, the E also left the room and they waited outside for 30 seconds before re-entering the room. On re-entering the room, the dog was led to the starting point by the owner and then it was released and allowed to search for the object until finding it. During this the owner was allowed to encourage his/her dog, but was instructed not to give any specific instructions and not to direct the dog toward any of the containers. All dogs received 5 trials in a predetermined order. Two different hiding orders (L3, R2, M, R3, L2 and R3, L2, M, L3, R2 respectively) were used and the order of the 5-trial blocks was counterbalanced across subjects in each group. The 2 terminal pots (R1 and L1 – see Figure 1) were never baited. Dogs had as much time as they needed to find the object.
After this the owners’ memory performance was measured by Kirschbaum et al’s declarative memory task (Kirschbaum et al. 1996). In the learning phase of the task the owners were given a list of 24 words for 5 minutes to read and memorize. This was followed by a 5 minute long distraction phase, during which they had to read a scientific paper about dog behaviour. Finally, owners were asked to recall those words (N=10) from the 24-words-list that begin with „mo” or „ko” (depending on the list) within 2 minutes. We used two different lists of words (word set A and B) and these were counterbalanced across conditions. Subjects in the Non-stressed owner condition were provided with a reading matter in the distraction phase which was easy to read and understand while subjects assigned to the Stressed owner condition were given a more challenging text. Dogs were together with their owners in the experimental room throughout the declarative memory task while the E was absent during the learning and distraction phases. Dogs were allowed to explore the environment, play and interact with their owners freely.

2.4.2. Phase 2 - manipulation

After this the E asked the owners several questions about the scientific article they had read during the distraction phase of the declarative memory task. This phase lasted for approximately 5 minutes. In the Stressed owner condition E gave mostly negative feedback and sometimes pointed out that the other participants were able to tell the right answer. However, in the Non-stressed owner condition the E gave only positive feedback and sometimes praised their performance by adding that the other participants were not able to tell the right answer.

This was followed by interactive situations, when owners were asked to complete different kinds of collaborative tasks together with their dogs. First a ball-carrying task.
during which the dog had to carry balls under the direction of its owner from a container into another one for 5 minutes. The containers were placed in two corners of the room and only one of the containers was baited with the balls. In the next 2 minutes they had to perform basic obedience tasks (sitting, laying and staying) and they also had the opportunity to show other tricks. The ball-carrying and obedience tasks were also accompanied by the experimenter’s negative or positive feedback. In the Non-stressed owner condition the E praised the dyads for performing the task well and did not comment the wrong performance. In the Stressed owner condition the E expressed her disapproval of the dyad’s bad wrong performance (in neutral speaking style) and did not comment on the instances where the dyad was successful. In the last 3-4 minutes of the manipulation the experimenter gave the text back to the owner for an additional 2 and a half minutes and in the next minute she asked further questions. Owners’ responses received either positive (Non-stressed condition) or negative (Stressed condition) reinforcement.

Importantly, both praise and disapproval were given by the E in a neutral tone of voice and she behaved in a neutral manner throughout Phase 2.

2.4.3. Phase 3 - measuring subjects’ performance after the manipulation

Owners were asked to fill out the same questionnaire (State- and Trait Anxiety Inventory) as in Phase 1.

Then we repeated the object hiding and finding tasks in order to measure the dogs’ ability to retain the location of a ball in their working memory. We used the exact same procedure as in Phase 1: First, dogs participated in the same memory task, however, they were provided with the other 5-trial blocks than in Phase 1 (as described above in the section about Phase 1). Then owners completed the same memory task as in Phase 1 with the only
exception that they were provided with the other set of words (A or B) and the reading
material in the distraction task was also different.

2.5. Procedure in the Control condition (Stressed dog)

2.5.1. Phase 1 – baseline measure

First, dogs participated in the same memory task as was described above in Phase 1 for
the other two conditions. This was followed by a 15 minute break, thus the time elapsed
between the first and the second memory task was the same as in the other two conditions.
During the break the owners and the dogs were sitting in the waiting room of the department.

2.5.2. Phase 2 - manipulation

After the break elapsed, the E introduced the dog and the owner to the experimental
room, then the owner left the scene and the dog was allowed to explore the room freely
in the presence of the E for 2.5 minutes. If the dog showed distress behaviours (see below)
less than 20 seconds long during this period the separation was continued for additional 2.5
minutes. If the dog showed signs of distress for at least 20 seconds, it was reunited with the
owner and phase 3 was administered. The E played with the dog or petted it depending on its
willingness.

2.5.3. Phase 3: measuring dogs’ performance after the manipulation

Using the same procedure as in Phase 1, we repeated the object hiding and finding
tasks, however, dogs were provided with a different order of object hiding trials.

2.6. Data collection
Owners anxiety/stress levels were measured by STAI scores consisting of two separate
20-item (rated from 1 to 4) self-report scales; one scale measures the state anxiety (s-STAI) and the other measures the trait anxiety (t-STAI, Sipos&Sipos 1983). Higher scores indicate increased level of anxiety. Based on the STAI scores measured repeatedly in Phase 1 (pre-manipulation) and Phase 3 (post-manipulation) we also calculated the change which indicates the effect of the manipulation on owners’ anxiety/stress levels in the different conditions.

Owner’s memory performance was measured by the number of words they could recall correctly. The change in their performance was also calculated as the difference between pre- and post-manipulation task performance.

Dog’s working memory performance was calculated on the basis of the number of erroneous choices (looking into an empty pot). The number of empty containers visited by the dog during trials 1-5 was added upsummarized and this was used as an indicator of task performance (higher scores indicates poorer memory abilities). The change in dogs’ working memory performance was also calculated as the difference between pre- and post-manipulation measures.

It was also measured how intensely the dogs were encouraged by their owners during the memory task. We coded the number of any kind of verbal encouragements (e.g.: Search! You can go! Where is the ball? Fetch the ball!) given by the owner during the trials.

The owner’s behaviour while interacting with his/her dog (in Phase 2 of the two experimental conditions) was also analysed using the following variables: relative duration of time spent with playing (i.e. any vigorous, toy-related behaviour between the dog and the owner); relative duration of time spent with physical contact (i.e. any form of bodily contact); number of positive (encouragement, praise etc.) and negative (prohibiting, scolding) verbal feedbacks provided by the owner.
In Phase 2, the number of positive (praise, telling it is a right answer) and negative (scolding, telling it is a wrong answer) verbal feedbacks provided by the Experimenter in response to the owners’ answers were also recorded.

In Phase 2 of the Stressed dog condition (control), while separated from their owners, dogs’ behaviour was recorded and the following five mutually exclusive behaviour categories were coded:

- Passive behaviours: standing, sitting or lying down.
- Exploration: activity directed toward non-movable aspects of the environment, including sniffing, distal visual inspection (staring or scanning), close visual inspection, or oral examination.
- Physical contact: any form of bodily contact with the experimenter
- Play: any vigorous, toy- or social partner-related behaviour, including running, jumping, or any physical contact with toys (chewing, biting)
- Distress behaviours: active behaviours resulting in physical contact with the door (scratching, jumping at etc.) and/or vocalising (i.e. barking, growling, howling, whining).

In order to exclude the possibility that dogs’ affective states were directly influenced by the experimenter during the manipulation phase in the two experimental conditions, a coder blind to both the condition and the purpose of the study coded the perceived stress level of the situation on a one-to-ten scale. Crucially, the coder did not speak the language that was used throughout the experiment; therefore he could not understand the content of the communication. He had to base his judgments on non-verbal gestures, tone of the voice and other non-linguistic cues, which resemble the information dogs may pick up on during the interaction between the experimenter and the owner.

2.7. Data analysis
First we employed a Generalized Estimating Equation for the analysis of the effect of the trial (performance before vs. after the manipulation) as within-subject factor and the effect of the type of the manipulation (Stressed owner vs. Non-stressed owner) as a between-subjects factor on the STAI scores and the memory performance of the owners. We performed the same analysis on the memory performance of the dogs with the modification that we included the Stressed dog condition in the type of manipulation variable and the previous training experience as covariate. For within-group comparisons Wilcoxon Matched-Pairs Ranks tests were used for discrete variables and paired t-tests for continuous variables (play and physical contact). For between-groups comparisons Mann-Whitney tests were used for discrete variables and unpaired t-tests for continuous variables. In the case of STAI scores and memory performances the changes due to the manipulation were calculated by subtracting the ‘before-manipulation’ values from the ‘after-manipulation’ values. The relationships between the variables were examined by Spearman correlation.

SPSS version 20 software was used for statistical analyses, all tests were two-tailed and the α value was set at 0.05.

3. Results

3.1. Changes in the owners’ trait and state anxiety levels (pre- vs. post manipulation periods)

The owners’ trait-anxiety seemed to be stable throughout the experiment; it was not influenced either by the trial (GEE, $\chi^2=1.166$ p=0.280) or by the type of manipulation ($\chi^2=1.239$ p=0.266) and the interaction was also not significant ($\chi^2=0.517$ p=0.472). In contrast, there was a significant interaction of the two main factors for the owners’ state
anxiety (GEE, $\chi^2=27.747$ p<0.001) without any significant main effects (trial: $\chi^2=0.009$ p=0.923 type of manipulation: $\chi^2=1.508$ p=0.219).

Owners in the *Stressed* condition received significantly more negative (p<0.001) and less positive (p<0.001) feedback than owners in the *Non-stressed* condition (Mann-Whitney tests, $U_{(35)}=0.00$ for both) and these different types of manipulations affected their affective status differently. Namely, owners after having received negative feedback from the experimenter(*Stressed owner* condition) reported significantly greater increase in their state anxiety in comparison with those who received only positive feedbacks (*Non-stressed owner* condition) during the manipulation phase (Mann-Whitney test, $U_{(35)}=12.5$ p<0.001) (Figure 2).

3.2. Owners’ memory performance (pre- vs. post manipulation periods - comparison between the two experimental conditions)

There was a significant trial X type of manipulation interaction on the owners’ memory performance (GEE, $\chi^2=8.248$ p=0.004) without any main effects (trial: $\chi^2=0.268$ p=0.605 type of manipulation: $\chi^2=0.008$ p=0.931). Although the initial performance did not differ between the two experimental conditions (Mann-Whitney test, $U_{(35)}=125$ p=0.169; Figure 3), the change in the number of recalled words was higher in the *Stressed owner* condition compared to the *Non-stressed owner* condition (Mann-Whitney test, $U_{(35)}=91$ p=0.014; Figure 4). This suggests that moderately increased anxiety improved the participants’ memory performance. Moreover the owners’ memory performance changed according to the change in their state anxiety (s-STAI) scores as was indicated by a positive correlation between them (Spearman’s rank correlation test, $r_{(35)}=0.39$ p=0.017).

3.3. Factors potentially influencing emotional contagion between dogs and their owners
In order to determine whether negative feedback given by the experimenter during the
Stressed condition have the potential to become a direct stressor for the dogs, we have
analysed the non-Hungarian coder’s ratings of perceived level of stressfulness in the
manipulation phase (Phase 2). Our analysis showed that based on the experimenter’s non-
verbal gestures, tone of the voice and other non-linguistic cues a human coder cannot
discriminate between the Stressed owner and the Non-stressed owner conditions (Mann-
Whitney test, $U_{(35)}=130.5; p=0.175$). This finding provides indirect evidence that stressing the
owner by the experimenter was not directly perceptible by the dogs.

We next investigated the possibility whether dogs’ stress level could be influenced
through their owners’ different behaviour in the manipulation phase of the Stressed vs. Non-
stressed condition. In fact, dogs got the opportunity to freely interact with their owners in
Phase 2 and thus we may assume that during this period the perception of expressive
behaviours of the owner can transfer emotional states from the owner to his/her dog. In line
with this assumption we coded and analysed the owners’ behaviour while interacting with
their dogs. Although there was no difference between the groups regarding the time spent
with physical contact (two sample t-test, $t_{(35)}=0.011 p=0.768$), dog-owner pairs in the Stressed
owner condition played less than in the Non-stressed owner condition ($t_{(35)}=2.069 p=0.01$).
Playing seems to be a good behavioural indicator of the owners’ distress, because it correlates
with the change in s-STAI (Spearman’s rank correlation test, $r_{(35)}=-0.453 p=0.005$) and with
the change in the owners’ memory performance as well ($r_{(35)}=-0.37 p=0.024$). Further
analyses showed that owners in both conditions gave more positive than negative
reinforcements (Wilcoxon Matched-Pairs Ranks tests, Stressed owner condition: $Z_{(18)}=-2.201$
p=0.028 Non-stressed owner condition: $Z_{(17)}=-3.726 p=<0.001$) and the number of negative
reinforcements were not significantly different between conditions (Mann-Whitney test,
$U_{(35)}=165 p=0.854$). At the same time dogs in the Non-stressed owner condition were
reinforced positively significantly more frequently than in the Stressed owner condition (U\(_{35}\)=86 p=0.01). These characteristic changes of the owners’ behaviour in the Stressed condition could potentially contribute to the contagion of stress in dog-human relationships.

3.4. Dogs’ behaviour during the separation phase (Stressed Dog condition, Phase 2)

All but two dogs showed active sign of distress for less than 20 sec (0-6.6 sec.) during the 2.5 minutes separation thus for these subjects (N=13) the duration of this episode was prolonged (+2.5 min.). The analysis of the relative percentage of the time spent within the different behaviours shows that dogs interacted with the experimenter on average 29.7\%(range 1.2-89.9\%) of the time on average. This was either physical contact (9.6±14.1\%) or playing (20.1±26.7\%) with the experimenter. They also explored the room (22.3±7.9\%, range 11.1-34.5\%) and behaved passively (30.2±19.2, range: 4.8-60.4\%). Dogs spent 17.7±15.6\% of time in close proximity (<1m) of the door but showed distress behaviours on average only 5.46±13.1\% (range: 0-50\%) of the total duration.

3.5. Dogs’ memory performance (pre- vs. post manipulation periods - comparison between all three conditions)

Analysing the dogs’ memory performance we found a significant main effect of trial (pre- vs. post manipulation periods; GEE, \(\chi^2=7.899\); p=0.005), without a main effects of type of manipulation (\(\chi^2=1.227\)); p=0.541493) or previous training experience (\(\chi^2=0.887\); p=0.346). More importantly there was an interaction between manipulation type and trial (\(\chi^2=11.873\)); p=0.002) (Figure 5). In comparison with their ‘baseline’ performance (Phase 1) dogs in both the Stressed owner and the Stressed dog conditions showed a significant improvement in the post-manipulation (Phase 3) working memory test (Wilcoxon Matched-Pairs Ranks tests, Stressed owner condition: Z\(_{18}\)=2.682 p=0.007, Stressed dog
condition: \( Z_{(13)}=2.253 \ p=0.024 \). In the Non-stressed owner condition, however, there was no change (\( Z_{(17)}=1.261 \ p=0.207 \)).

The finding that dogs’ working memory performance varied as a function of the manipulation in Phase 2 was further supported by the analysis of the difference between pre- and post-manipulation measures. That is, the number of errors changed differently in the three conditions (Kruskal Wallis test \( \chi^2_{(2)}=10.641 \ p=0.0049 \); pairwise comparisons with Bonferroni correction: Stressed owner vs. Non-stressed owner: \( p<0.05 \); Stressed dog vs. Non-stressed owner: \( p<0.05 \)). Dogs in the Stressed conditions showed an improved memory performance (Figure 65).

There is a negative correlation between the change in number of errors and the change in the owners’ stress level (Spearman’s rank correlation test, \( r_{(35)}=-0.483 \ p=0.002 \) which suggest that dogs’ performance was affected by their owners’ affective states. It is also worth mentioning that dogs’ change in memory performance also correlated with the relative time spent with playing (\( r_{(35)}=0.439 \ p=0.007 \), dogs whose owners tended to play more with them during the manipulation phase committed more errors when re-tested in the memory task (Phase 3).

Dogs’ better performance in the two Stressed conditions cannot be explained by the owners’ more explicit encouragement, because the number of (verbal) encouragements did not differ between the pre- and post-manipulation phases (Phase 1 vs. Phase 3, Wilcoxon Matched-Pairs Ranks tests, Stressed dog condition: \( Z_{(14)}=29 \ p=0.21 \); Stressed owner condition: \( Z_{(18)}=-1.122 \ p=0.262 \); Non-stressed owner condition: \( Z_{(17)}=-0.855 \ p=0.393 \)). Moreover there is no significant differences between the three groups (Kruskall Wallis test, before the manipulation: \( \chi^2_{(2)}=1.56p=0.46 \)after the manipulation: \( \chi^2_{(2)}=3.08p=0.21 \). In addition, we analyzed whether previous training experience influenced dogs’ memory performance. We compared the performance of dogs that had received some sort of
official training (33) with those that had not (19), and found no difference either before
(Mann-Whitney test \(U_{(51)}=259.5\ p=0.302\)) or after (\(U_{(51)}=285.5\ p=0.592\)) the manipulation.
The change in performance was not affected by previous training either (\(U_{(51)}=268.5\ p=0.389\)).

4. Discussion

In the current study we aimed to investigate the emotional contagion between dogs
and owners and examined whether dogs show some sign of taking over their owners’
affective inner state in a case where only the owner’s affective inner state was manipulated. We
also investigated whether the effects of this kind of contagion of an emotional state (increased
level of stress) transfer to a different domain by affecting an aspect of cognitive performance
as well. It has been shown that stress and stress hormones influence cognitive performance
following an inverse U shape dose-response relationship in both humans (Belanoff et al.
2001) and nonhuman animals (Roozendaal 2000; Salehi et al. 2010), so low to moderate
levels of distress have an improving effect on cognitive functions (Shors et al. 1989).

Psychological stress can also cause physiological changes (Chida & Hamer 2008) and it
mainly affects the hippocampus, the area of the declarative memory (Diamond et al. 1994).

Our results are in line with this notion. The analyses of our data allow us to conclude that the
owners' state anxiety was effectively manipulated by the experimenter (i.e. after having
received negative feedbacks, owners achieved higher state anxiety scores). The owners' performance in the declarative memory task also seems to be affected by their anxiety level,
leading to a better performance in the Stressed owner condition and findings from the
Stressed dog condition indicate a similar effect of anxiety on dogs’ spatial working memory.

Moreover, dogs’ working memory performance significantly correlated with the change in the
owners’ self-reported stress level and changed in the same direction as the owners’ memory performance. This raises the possibility that their owners’ state anxiety is contagious to dogs and the emotional contagion can be tracked by measuring changes in dogs’ memory performance.

It is important to note that owners’ improved performance in a stressful situation could not only be generated by the moderately increased stress levels; but could also be facilitated by the procedure, by the method of the manipulation. Namely, negative verbal feedback in a skill performance situation can be regarded as a kind of failure, and this can inspire people to perform better in the next task independent of the increased level of stress that negative feedback supposedly elicits. However, the literature also provides evidence suggesting that feelings of failure, when losing a competition, can cause stress hormone release (Bhatnagar & Vining 2003), therefore it may not be possible to disentangle these two seemingly different effects. Moreover, perceiving a situation more or less stressful depends on personality as well (Wirth et al 2006).

One possible alternative explanation of our results could be based on that due to the discrepancy in the difficulty of the initial task. That is, owners performed more poorly in the baseline phase of the Stressed owner condition because they had a more difficult text to read and therefore they had more room for improvement by the end of the experiment. However, this is not likely since there was no main effect of condition on the memory performance of owners and pairwise analyses also confirm the notion that initial performance did not differ between the two experimental conditions. The declining memory performance in the Non-stressed owner condition can be best explained by fatigue, because participants had to read and learn a lot and solve several tasks during the long time of the experiment. On the other hand they probably did not feel any motivation to perform better at the end of the experiment.
Another factor that could have influenced the success of the manipulation is the dogs’ level of training. It could be argued that since we expected the transmission of affective state to happen – at least partly – during an obedience task, dogs that had gone through obedience training might respond differently and may not experience that much stress (or alternatively may be more attuned to the owner and therefore be more sensitive to their signals). However, we have shown that the change in memory performance did not depend on the level of training, therefore this explanation can be ruled out.

A key finding of the present study is that the anxiety stress experienced by the owner influences contagious to their dog’s behaviour and that these effects are manifested in also transferred to the cognitive domain. We propose that this phenomenon can be best explained by emotion contagion as the dogs’ performance was not directly reliant on the owner’s affective state or behaviour. Dogs had to solve the task on their own, therefore any change in performance had to be the result of previous interactions. Since very similar effects were observed in the memory performance of the owners, it is plausible to assume that the change of affective state was also similar.

The improvement of spatial working memory performance of dogs in the Stressed owner condition was similar to that of the Stressed dog condition. Since there were significant differences in the owners’ play behaviour and the use of positive reinforcements while interacting with their dogs, we may assume that the owners’ affective inner state was transmitted at least partly through these behaviour signals. Of course dogs could be influenced by other sources of information, for example the owners’ body language (Merola et al. 2012), facial expression (Nagasawa et al. 2011; Racca et al. 2012), emotional valence of the commands (Ruffman & Morris-Trainor 2011), or other unobservable behavioural signals or odour cues (Prehn-Kristensen et al. 2009).
One of the most important questions in the literature on emotional contagion concerns the problem of how these behavioural cues contribute to the transmission of emotions. Taking an interspecies approach to the question can shed some further light on the matter. Non-conscious mimicry of expressions has been suggested to play a key role in intraspecies cases (e.g. Hatfield et al. 1993) during which the emotional expression of one individual is imitated by the observer, generating a similar feeling in him/her too. However, non-conscious mimicry is unlikely to work properly between individuals of a different species. Therefore it seems a plausible explanation that a more sophisticated perception of the social context contributes to the phenomenon and that it cannot be accounted for by such direct physiological changes. The importance of a higher level of social sensitivity is also in line with findings that show that less social species, such as the red-footed tortoise, are not susceptible to a related phenomenon, contagious yawning (Wilkinson et al. 2011). The dog’s special sensitivity to human behavioural cues, however, can lead to the appearance of emotional contagion between different species and may also serve similar functions as in a human-to-human interaction.

In sum, we showed similar effects in dogs as in their owners with direct manipulation of the owners only, supporting the existence of the emotional contagion between two different species. Recent experimental data suggest that dogs’ behaviour can be influenced by the pretended emotion of a human. For example they show an empathic-like response toward a crying human (Custance & Mayer 2012), and react to an unfamiliar object according to the owner’s attitude (Merola et al. 2012). The current study extends our understanding of these results since the change in the memory performance observed in dogs is unlikely to be attributed to any conditioned response to the behavioural cues of the human. Furthermore, this study gives further support for the idea that the real emotions of the owner can influence the dog; and our results suggest that the underlying mechanism more over the
owner’s inner state seems to be contagious to the dog may be emotion contagion. This points to the conclusion that it is possible to influence the dog’s stress level via the owner even in an artificial situation. We suggest that these effects are due to the special domestication history of the dog that has endowed this species with a unique sensitivity to the behavioural cues of humans.

Acknowledgements

Financial support was provided by the Hungarian Scientific Research Fund (OTKA K-100695).

Ethical standards

The experiments comply with the current Hungarian laws.

References


e78455. doi:10.1371/journal.pone.0078455


Figure 1: Experimental arrangement of the dog Spatial Working Memory task. The owner made the dog sit equidistant from the 7 plastic containers serving as hiding places. The positions of the containers are labelled as L(left) 1-3, R(right) 1-3 and M(middle).

Figure 2: Comparison of the owners’ state-anxiety scores obtained from pre- and post-manipulation phases (median, quartiles and extreme values) in the Non-stressed- and Stressed owner conditions. (* p<0.001)

Figure 3: Number of words recalled by the owners in the declarative memory task before and after the manipulation.

Figure 4: Changes in the number of words (pre- vs. post-manipulation phases; median, quartiles and extreme values) recalled by the owners in the declarative memory task. (* p = 0.014)

Figure 5: Number of erroneous choices (pre- vs. post-manipulation phases; median, quartiles and extreme values) by the dogs in the memory task. (* p < 0.05)

Figure 6: Changes in the number of dogs’ erroneous choices in the Spatial Working Memory task (pre- vs. post-manipulation phases; median quartiles and extreme values. (* p=0.0049)
Emotional contagion in dogs as measured by change in cognitive task performance.

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Abstract
Domestic dogs are living with humans in a very special inter-species relationship. Previous studies have shown physiological and hormonal synchronisation between dogs and their owners during positive interaction. Dogs are also known to be able to discriminate human emotions and they were also presupposed to have the capacity to empathise with humans. Based on these results we hypothesize that the owner’s emotions can be contagious to the dog and stress-related emotional changes in dogs can be tracked by memory tasks because both human and nonhuman studies indicate a significant effect of perceived stress on subjects’ cognitive performance. In the present study the owners, after having completed State Anxiety Inventory and having participated in a memory task, were manipulated with either negative (Stressed owner condition) or positive (Non-stressed owner condition) verbal feedback in an additional task. Results indicate that the owners’ self-reported anxiety significantly increased
in the *Stressed owner* condition due to the manipulation. We also measured the effect of the different manipulations on the owners’ and also on their dogs’ memory performance and found that in line with earlier studies the stress-evoking intervention had an improving effect on the owners’ memory performance. After separation from their owner (*Stressed dog* condition) dogs also showed better performance in a spatial working memory task and, more interestingly, task completion was also affected by the manipulation of their owners stress level. These findings provide further support for the emotional contagion between dogs and their owners, and suggest that measuring changes in the memory performance can be used as an indicator of contagion-induced changes in dogs’ stress level.

**keywords:** emotional contagion, dog-owner relationship, stress, memory

**Research highlights**

1 Stress has an improving effect on the humans’ and dogs’ memory performance.

2 Dogs’ memory performance can be affected by their owners’ stress level.

3 Our results support for the emotional contagion between dogs and their owners.
1. Introduction

Emotional contagion, a concept coined by Hatfield et al (1992) can be described as an automatic response to perceiving another’s emotional state through which a similar emotional response is triggered in the observer. The phenomenon can be seen as a primitive form of empathy which appears to be widespread amongst mammals. However it is widely accepted that the contagion of emotional responses does not require the ability to differentiate between own and other’s emotions or any conscious control over emotional reactivity (Preston & de Waal 2002).

Emotional contagion has been extensively examined in rodents (for a review see Edgar et al. 2012). For example social transmission of fear response has been reported in rats (Knapska et al. 2010) and pain sensitivity in mice also seems to be influenced by a conspecific’s pain response (Langford et al. 2006, Jeon et al. 2010). Birds may also show evidence of emotional contagion, greylag geese (Wascher et al. 2008) as well as chickens (Edgar et al 2011) show physiological responses while observing distressed conspecifics. Regarding the empathic abilities of nonhuman primates there is evidence for contagious yawning in both apes (chimpanzees - Anderson et al. 2004) and monkeys (macaques – Paukner & Anderson 2006) and rapid facial reactions to the partner’s emotional facial expression during play has been described in orangutans (facial mimicry - Ross et al. 2008).

There is ample evidence that empathic-like responding is usually more pronounced between familiar conspecifics than unfamiliar peers (e.g. Langford et al. 2006, Ben-Ami Bartal et al. 2011, Ma et al. 2011), importantly, however, contagious behaviour can occur also in heterospecific contexts. A recent study provides support for the notion of cross-species contagious yawning in chimpanzees (Madsen et al. 2013) and there is ample evidence suggesting emotionally connected heterospecific yawn contagion in dogs (Joly-Maschoni et al. 2008, Silva et al. 2012, Romero et al. 2013).
Human-dog cross-species contagious yawning has a potential link with the specific social-cognitive capacities of the domestic dog (Yoon & Tennie 2010). In fact, many assume that dogs are socially tuned-in to humans because as a result of their unique domestication process, they have developed an evolutionary novel, inter-specific type of social competence which, among others, allowed for the establishment of a wide range of affiliative social relationships with humans (Miklósi & Topál 2013). The relationship between the dog and its owner is functionally similar to the mother-infant attachment (see Topál & Gácsi 2012 for a review) which is considered essential for the development of dogs’ emotional responsiveness (Plutchik 1987). Moreover, a recent study has found a correlation between the owner’s attachment profile and the quality of the dog-owner attachment bond (Siniscalchi et al. 2013). In addition to providing further support for the notion that the dog-owner relationship resembles the connection between a mother and her child, these results also support the idea that dogs tend to assimilate the characteristics of their owners and this is manifested in their affective stance.

Moreover dogs and children tend to correspond in the degree to which they are able to react to the challenges of human communication (see Topál et al. 2014, for a review). They possess enhanced skills in reading human visual attention (e.g. Kaminski et al. 2009) and show special responsiveness to human gestural communication (e.g. Lakatos et al. 2012). Dogs can also learn to discriminate between different human emotional expressions (Deputte & Doll 2011, Nagasawa et al. 2011; Racca et al. 2012) and respond differently to commands given with emotionally different tones of voice (Ruffman & Morris-Trainor 2011). They are not only sensitive to the emotional state of their owners (Morisaki et al. 2009), but their behaviour can even be influenced by the owner’s emotional expression (Merola et al. 2012).

Dogs’ interspecific social- and emotional responsiveness is further supported by recent investigations (Silva & Sousa 2011, Romero et al. 2013) that raised the possibility that dogs
have the ability to feel humans’ emotional experiences (‘affective empathy’). It is worth mentioning, that unlike the cognitive empathy system which entails representing another’s emotional experience (deWaal 2008), affective empathy, is often described as an ‘automatic’ process (Hatfield et al. 1993) stemming from an unconscious social contagion system. That is, instead of being able to represent another’s emotional experience (cognitive empathy) dogs may have affective responses to the observed emotion of the human (i.e. feel what the human feels).

Social contagion can be seen as the rudimentary mechanism that serves to synchronize partners at different levels (physiological, emotional and behavioural synchronization). There is some experimental evidence suggesting hormonal and physiological synchronisation between owners and their pet dogs. Affiliative interactions between dogs and humans can have stress relieving effects; lower cortisol level as well as increased oxytocin and dopamine levels in both species (Odendaal & Meintjes 2003, Miller at al. 2009, Handlin et al. 2012). Hormonal interactions between people and dogs may also occur under conditions of psychological stress (e.g. after losing a competition -Wirth et al. 2006). For example, Jones and Josephs(2006) investigated the hormonal changes in dog-human teams during agility competition and found that in losing teams, unlike in winning ones, the owners’ pre-competition basal testosterone levels and their pre- to post-competition changes in testosterone are significant predictors of dogs’ changes in cortisol level.

In addition to direct measurement of hormonal changes, the effects of stress on subjects’ internal state can also be assessed indirectly; either by using questionnaires (e.g. Frankenhaeuser et al. 1978) or by measuring changes in subjects’ cognitive performance. Some studies suggest that stress hormones can have an inverted-U shape effect on learning and memory in both humans and nonhuman animals (McEwen & Sapolsky 1995; Belanoff et
al. 2001). While moderate stress has been shown to positively impact memory retention, high stress levels can lead to impaired cognitive performance.

Although findings suggest that dogs show high responsiveness to changes in their human caregiver’s stress status, and there is also evidence that stress-related emotional changes can be tracked by memory tasks, investigation of the association between stress-induced changes in owners and their dogs as measured by changes in their memory performance is lacking in the literature.

In the current study we investigated whether pet dogs can take over the emotional state of their owners in the context of experimentally induced anxiety and whether changes in their owners’ affective states have an effect on dogs’ memory performance. Owners’ anxiety levels were experimentally manipulated: they were told that they were participating in a task designed to measure one aspect of their cognitive performance, a ‘word list memory task’ (WMT). Owners were assigned either to the Non-stressed or the Stressed condition in which the difficulty of the task and the amount of experimenter-delivered positive/negative verbal feedback were surreptitiously manipulated. We predicted that (I) our procedure should be sufficient to increase the owners’ self-reported stress/anxiety in the ‘stressed’ condition; (II) these changes should have an effect on owners’ memory performance in the WMT and (III) the changes in owners’ affective states should be contagious to dogs and the emotional contagion should be manifested in changes in the dogs’ memory performance. As a control, we also ran a condition in which the dog’s stress level was directly manipulated (Stressed dog condition) as opposed to being indirectly affected through the emotional state of the owner. This allowed us to test whether the potential change in cognitive performance following an indirect manipulation is comparable to that in case of more direct effects. We used the ‘separation paradigm’ because ample evidence suggests that separation from the owner in
unfamiliar environments evokes moderate stress and anxiety in dogs (see Topál & Gácsi 2012 for a review).

2. Materials and Methods

2.1. Subjects

52 dogs (mean age ±SD: 3.81±1.82 years, 26 males and 26 females) participated in the study on a voluntary basis. Out of the 52 dogs, 37 were tested together with their owners (experimental conditions; owners’ mean age ±SD: 30.5±8.4 years, 34 women and 3 men) Subjects were randomly assigned to one of the following three conditions: Stressed owner (n=19), Non-stressed owner (n=18), Stressed dog (n=15). In the subsequent sections, we refer to the first two conditions as "experimental" and to the third one as "control". The dogs were from 18 different breeds (8 Golden retrievers, 5 Border collies, 3-3 Fox terriers, Hungarian vizslas, Labrador retrievers, 2-2 Collies, West highland terriers, 1-1 Boxer, Chihuahua, Dalmatian, Havanese, Jack Russel terrier, German shepherd, Schipperke, Yorkshire terrier, Poodle, Rottweiler, Shiba Inu) and 15 mongrels. Dogs’ previous training experience was also assessed. Out of all the participants, 33 dogs had received some sort of obedience training, while 19 had never participated in any formal training. However, the distribution of “trained” and “untrained” dogs did not differ significantly across conditions, with 13, 12 and 8 trained dogs in the Stressed-owner, Non-stressed owner and Stressed dog conditions, respectively ($\chi^2$(2)=1.25; p=0.53)

2.2. Experimental arrangement
The experiment took place in a room (3.9 m x 4.1 m) at the Dept. of Ethology, Eötvös University, Budapest. Only a chair and some toys (a tennis ball and a rope) for the dog were placed in the room. These toys were present during the whole experiment, except for the dog memory tasks (see below) when only one ball as target object and 7 plastic flowerpots as hiding places were used. However in the ball-carrying task (Phase 2 – see below) and during the second dog memory task (Phase 3 – see below) additional balls (2-3) and containers (2) were also present.

2.3. Overview of the experimental procedure

The procedure consisted of three phases for both the experimental and the control conditions. In the experimental conditions the pre-manipulation phase (Phase 1) started by assessing the owners’ baseline anxiety level (using a state anxiety questionnaire) and their memory performance (in a word list memory task) and we also measured the dogs’ ability to retain the location of a ball in their working memory (in an object hiding and finding task). In the control condition, only the dog memory task was administered in phase 1. This was followed by the manipulation (Phase 2) during which the owners in the experimental conditions had to answer questions about an article they had read before and they were also asked to complete collaborative tasks together with their dogs. The latter part was added to the procedure to enable the transfer of stress/anxiety between the human and his/her dog. Importantly, owners in the Stressed owner condition received mostly negative feedback, while owners in the Non-stressed owner condition were given only positive feedback. In the Stressed dog condition, the dog’s anxiety level was manipulated by introducing a short period of separation from the owner. Finally, in the test phase (Phase 3), the owners’ and their dogs’ memory performances as well as the owners’ state anxiety were re-tested using the same
methods as used in Phase 1. In the control condition, only dogs’ memory performance was assessed.

2.4. Procedure of the experimental conditions (Stressed owner and Non-stressed owner)

2.4.1. Phase 1 – Baseline measures

Right after their arrival, the owners filled out the Hungarian version of the State- and Trait Anxiety Inventory (STAI; Sipos & Sipos 1983) which is widely used by psychologists to measure anxiety both at a particular point in time (state) and in general (trait).

After this the owner and his/her dog were led into the experimental room by the Experimenter (E) and were allowed to explore the room for a few minutes. Then the owner made the dog sit at a predetermined starting point and the E placed seven identical brown plastic flowerpots (11 cm high, 14 cm in diameter) on the floor in a semicircle (Figure 1). The dog was sitting equidistant from the bowls (3 meters away) while being held by the owner. The E then took the target object (a tennis ball), showed it to the dog, walked straight towards one hiding location, and placed the ball into the pot clearly visibly to the dog. After the hiding event the dog was led out of the room by the owner, the E also left the room and they waited outside for 30 seconds before re-entering the room. On re-entering the room, the dog was led to the starting point by the owner and then it was released and allowed to search for the object until finding it. During this the owner was allowed to encourage his/her dog, but was instructed not to give any specific instructions and not to direct the dog toward any of the containers. All dogs received 5 trials in a predetermined order. Two different hiding orders (L3, R2, M, R3, L2 and R3, L2, M, L3, R2 respectively) were used and the order of the 5-trial blocks was counterbalanced across subjects in each group. The 2 terminal pots (R1 and L1 – see Figure 1) were never baited. Dogs had as much time as they needed to find the object.
After this the owners’ memory performance was measured by Kirschbaum et al’s declarative memory task (Kirschbaum et al. 1996). In the learning phase of the task the owners were given a list of 24 words for 5 minutes to read and memorize. This was followed by a 5 minute long distraction phase, during which they had to read a scientific paper about dog behaviour. Finally, owners were asked to recall those words (N=10) from the 24-words-list that begin with „mo” or „ko” (depending on the list) within 2 minutes. We used two different lists of words (word set A and B) and these were counterbalanced across conditions. Subjects in the Non-stressed owner condition were provided with a reading matter in the distraction phase which was easy to read and understand while subjects assigned to the Stressed owner condition were given a more challenging text. Dogs were together with their owners in the experimental room throughout the declarative memory task while the E was absent during the learning and distraction phases. Dogs were allowed to explore the environment, play and interact with their owners freely.

2.4.2. Phase 2 - manipulation

After this the E asked the owners several questions about the scientific article they had read during the distraction phase of the declarative memory task. This phase lasted for approximately 5 minutes. In the Stressed owner condition E gave mostly negative feedback and sometimes pointed out that the other participants were able to tell the right answer. However, in the Non-stressed owner condition the E gave only positive feedback and sometimes praised their performance by adding that the other participants were not able to tell the right answer.

This was followed by interactive situations, when owners were asked to complete different kinds of collaborative tasks together with their dogs. First a ball-carrying task, during which the dog had to carry balls under the direction of its owner from a container into
another one for 5 minutes. The containers were placed in two corners of the room and only
one of the containers was baited with the balls. In the next 2 minutes they had to perform
basic obedience tasks (sitting, laying and staying) and they also had the opportunity to show
other tricks. The ball-carrying and obedience tasks were also accompanied by the
experimenter’s negative or positive feedback. In the Non-stressed owner condition the E
praised the dyads for performing the task well and did not comment the wrong performance.
In the Stressed owner condition the E expressed her disapproval of the dyad’s bad
performance (in neutral speaking style) and did not comment on the instances where the dyad
was successful. In the last 3-4 minutes of the manipulation the experimenter gave the text
back to the owner for an additional 2 and a half minutes and in the next minute she asked
further questions. Owners’ responses received either positive (Non-stressed condition) or
negative (Stressed condition) reinforcement.
Importantly, both praise and disapproval were given by the E in a neutral tone of voice and
she behaved in a neutral manner throughout Phase 2.

2.4.3. Phase 3 - measuring subjects’ performance after the manipulation

Owners were asked to fill out the same questionnaire (State- and Trait Anxiety
Inventory) as in Phase 1.

Then we repeated the object hiding and finding tasks in order to measure the dogs’
ability to retain the location of a ball in their working memory. We used the exact same
procedure as in Phase 1: first, dogs participated in the same memory task, however, they were
provided with the other 5-trial block than in Phase 1 (as described above in the section about
Phase 1). Then owners completed the same memory task as in Phase 1 with the only
exception that they were provided with the other set of words (A or B) and the reading
material in the distraction task was also different.
2.5. Procedure in the Control condition (Stressed dog)

2.5.1. Phase 1 – baseline measure

First, dogs participated in the same memory task as was described above in Phase 1 for the other two conditions. This was followed by a 15 minute break, thus the time elapsed between the first and the second memory task was the same as in the other two conditions. During the break the owners and the dogs were sitting in the waiting room of the department.

2.5.2. Phase 2 – manipulation

After the break elapsed, the E introduced the dog and the owner to the experimental room, then the owner left the scene and the dog was allowed to explore the room freely in the presence of the E for 2.5 minutes. If the dog showed distress behaviours (see below) less than 20 seconds long during this period the separation was continued for additional 2.5 minutes. If the dog showed signs of distress for at least 20 seconds, it was reunited with the owner and phase 3 was administered. The E played with the dog or petted it depending on its willingness.

2.5.3. Phase 3: measuring dogs’ performance after the manipulation

Using the same procedure as in Phase 1, we repeated the object hiding and finding tasks, however, dogs were provided with a different order of object hiding trials.

2.6. Data collection
Owners' anxiety levels were measured by STAI scores consisting of two separate 20-item (rated from 1 to 4) self-report scales; one scale measures state anxiety (s-STAI) and the other measures trait anxiety (t-STAI, Sipos&Sipos 1983). Higher scores indicate increased level of anxiety. Based on the STAI scores measured repeatedly in Phase 1 (pre-manipulation) and Phase 3 (post-manipulation) we also calculated the change which indicates the effect of the manipulation on owners' anxiety levels in the different conditions.

Owner's memory performance was measured by the number of words they could recall correctly. The change in their performance was also calculated as the difference between pre- and post-manipulation task performance.

Dog's working memory performance was calculated on the basis of the number of erroneous choices (looking into an empty pot). The number of empty containers visited by the dog during trials 1-5 was added up and this was used as an indicator of task performance (higher scores indicates poorer memory abilities). The change in dogs' working memory performance was also calculated as the difference between pre- and post-manipulation measures.

It was also measured how intensely the dogs were encouraged by their owners during the memory task. We coded the number of any kind of verbal encouragements (e.g.: Search! You can go! Where is the ball? Fetch the ball!) given by the owner during the trials.

The owner's behaviour while interacting with his/her dog (in Phase 2 of the two experimental conditions) was also analysed using the following variables: relative duration of time spent with playing (i.e. any vigorous, toy-related behaviour between the dog and the owner); relative duration of time spent with physical contact (i.e. any form of bodily contact); number of positive (encouragement, praise etc.) and negative (prohibiting, scolding) verbal feedback provided by the owner.
In Phase 2, the number of positive (praise, telling it is a right answer) and negative (scolding, telling it is a wrong answer) verbal feedback provided by the Experimenter in response to the owners’ answers were also recorded.

In Phase 2 of the Stressed dog condition (control), while separated from their owners, dogs’ behaviour was recorded and the following five mutually exclusive behaviour categories were coded:

- Passive behaviours: standing, sitting or lying down.
- Exploration: activity directed toward non-movable aspects of the environment, including sniffing, distal visual inspection (staring or scanning), close visual inspection, or oral examination.
- Physical contact: any form of bodily contact with the experimenter
- Play: any vigorous, toy- or social partner-related behaviour, including running, jumping, or any physical contact with toys (chewing, biting)
- Distress behaviours: active behaviours resulting in physical contact with the door (scratching, jumping at etc.) and/or vocalising (i.e. barking, growling, howling, whining).

In order to exclude the possibility that dogs’ affective states were directly influenced by the experimenter during the manipulation phase in the two experimental conditions, a coder blind to both the condition and the purpose of the study coded the perceived stress level of the situation on a one-to-ten scale. Crucially, the coder did not speak the language that was used throughout the experiment; therefore he could not understand the content of the communication. He had to base his judgments on non-verbal gestures, tone of the voice and other non-linguistic cues, which resemble the information dogs may pick up on during the interaction between the experimenter and the owner.

2.7. Data analysis
First we employed a Generalized Estimating Equation for the analysis of the effect of the trial (performance before vs. after the manipulation) as within-subject factor and the effect of the type of the manipulation (Stressed owner vs. Non-stressed owner) as a between-subjects factor on the STAI scores and the memory performance of the owners. We performed the same analysis on the memory performance of the dogs with the modification that we included the Stressed dog condition in the type of manipulation variable and the previous training experience as covariate. For within-group comparisons Wilcoxon Matched-Pairs Ranks tests were used for discrete variables and paired t-tests for continuous variables (play and physical contact). For between-groups comparisons Mann-Whitney tests were used for discrete variables and unpaired t-tests for continuous variables. In the case of STAI scores and memory performances the changes due to the manipulation were calculated by subtracting the ‘before-manipulation’ values from the ‘after-manipulation’ values. The relationships between the variables were examined by Spearman correlation.

SPSS version 20 software was used for statistical analyses, all tests were two-tailed and the α value was set at 0.05.

3. Results

3.1. Changes in the owners’ trait and state anxiety levels (pre- vs. post manipulation periods)

The owners’ trait-anxiety seemed to be stable throughout the experiment; it was not influenced either by the trial (GEE, $\chi^2=1.166$ p=0.280) or by the type of manipulation ($\chi^2=1.239$ p=0.266) and the interaction was also not significant ($\chi^2=0.517$ p=0.472). In contrast, there was a significant interaction of the two main factors for the owners’ state
anxiety (GEE, $\chi^2=27.747 \ p<0.001$) without any significant main effects (trial: $\chi^2=0.009$
p=0.923 type of manipulation: $\chi^2=1.508 \ p=0.219$).

Owners in the Stressed condition received significantly more negative (p<0.001) and
less positive (p<0.001) feedback than owners in the Non-stressed condition (Mann-Whitney
tests, $U_{(35)}=0.00$ for both) and these different types of manipulations affected their affective
status differently. Namely, owners after having received negative feedback from the
experimenter (Stressed owner condition) reported significantly greater increase in their state
anxiety in comparison with those who received only positive feedbacks (Non-stressed owner
condition) during the manipulation phase (Mann-Whitney test, $U_{(35)}=12.5 \ p<0.001$) (Figure
2).

3.2. Owners’ memory performance (pre- vs. post manipulation periods - comparison
between the two experimental conditions)

There was a significant trial X type of manipulation interaction on the owners’
memory performance (GEE, $\chi^2=8.248 \ p=0.004$) without any main effects (trial: $\chi^2=0.268 \ p=
0.605$ type of manipulation: $\chi^2=0.008 \ p=0.931$). Although the initial performance did not
differ between the two experimental conditions (Mann-Whitney test, $U_{(35)}=125 \ p=0.169$;
Figure 3), the change in the number of recalled words was higher in the Stressed owner
condition compared to the Non-stressed owner condition (Mann-Whitney test, $U_{(35)}=91$
p=0.014; Figure 4). This suggests that moderately increased anxiety improved the participants’
memory performance. Moreover the owners’ memory performance changed according to the
change in their state anxiety (s-STAI) scores as was indicated by a positive correlation
between them (Spearman’s rank correlation test, $r_{(35)}=0.39 \ p=0.017$).

3.3. Factors potentially influencing emotional contagion between dogs and their owners
In order to determine whether negative feedback given by the experimenter during the
Stressed condition have the potential to become a direct stressor for the dogs, we have
analysed the non-Hungarian coder’s ratings of perceived level of stressfulness in the
manipulation phase (Phase 2). Our analysis showed that based on the experimenter’s non-
verbal gestures, tone of the voice and other non-linguistic cues a human coder cannot
discriminate between the Stressed owner and the Non-stressed owner conditions (Mann-
Whitney test, $U_{(35)}=130.5; p=0.175$). This finding provides indirect evidence that stressing the
owner by the E was not directly perceptible by the dogs.

We next investigated the possibility whether dogs’ stress level could be influenced
through their owners’ different behaviour in the manipulation phase of the Stressed vs. Non-
stressed condition. In fact, dogs got the opportunity to freely interact with their owners in
Phase 2 and thus we may assume that during this period the perception of expressive
behaviours of the owner can transfer emotional states from the owner to his/her dog. In line
with this assumption we coded and analysed the owners’ behaviour while interacting with
their dogs. Although there was no difference between the groups regarding the time spent
with physical contact (two sample t-test, $t_{(35)}=0.011\ p=0.768$), dog-owner pairs in the Stressed
owner condition played less than in the Non-stressed owner condition ($t_{(35)}=2.069\ p=0.01$).
Playing seems to be a good behavioural indicator of the owners’ distress, because it correlates
with the change in s-STAI (Spearman’s rank correlation test, $r_{(35)}=-0.453\ p=0.005$) and with
the change in the owners’ memory performance as well ($r_{(35)}=-0.37\ p=0.024$). Further
analyses showed that owners in both conditions gave more positive than negative
reinforcements (Wilcoxon Matched-Pairs Ranks tests, Stressed owner condition: $Z_{(18)}=-2.201$
p=0.028 Non-stressed owner condition: $Z_{(17)}=3.726\ p<0.001$) and the number of negative
reinforcements were not significantly different between conditions (Mann-Whitney test,
$U_{(35)}=165\ p=0.854$). At the same time dogs in the Non-stressed owner condition were
reinforced positively significantly more frequently than in the *Stressed owner* condition (U\(_{(35)}=86\) \(p=0.01\)). These characteristic changes of the owners’ behaviour in the Stressed condition could potentially contribute to the contagion of stress in dog-human relationships.

3.4.Dogs’ behaviour during the separation phase (*Stressed Dog condition, Phase 2*)

All but two dogs showed active sign of distress for less than 20 sec (0-6.6 sec.) during the 2.5 minutes separation thus for these subjects (N=13) the duration of this episode was prolonged (+2.5 min.). The analysis of the relative percentage of the time spent with the different behaviours shows that dogs interacted with the experimenter 29.7% (range 1.2-89.9%) of the time on average. This was either physical contact (9.6±14.1%) or playing (20.1±26.7%) with the experimenter. They also explored the room (22.3±7.9%, range 11.1-34.5%) and behaved passively (30.2±19.2, range: 4.8-60.4%). Dogs spent 17.7±15.6% of time in close proximity (<1m) of the door but showed distress behaviours on average only 5.46±13.1% (range: 0-50%) of the total duration.

3.5.Dogs’ memory performance (pre- vs. post manipulation periods - comparison between all three conditions)

Analysing the dogs’ memory performance we found a significant main effect of trial (pre- vs. post manipulation periods: GEE, \(\chi^2=7.89; p=0.005\), without a main effect of type of manipulation (\(\chi^2=1.227; p=0.541\)) or previous training experience (\(\chi^2=0.887; p=0.346\)). More importantly there was an interaction between manipulation type and trial (\(\chi^2=12.464 p=0.002\)) (Figure 5). In comparison with their ‘baseline’ performance (Phase 1) dogs in both the *Stressed owner* and the *Stressed dog* conditions showed a significant improvement in the post-manipulation (Phase 3) working memory test (Wilcoxon Matched-Pairs Ranks tests, *Stressed owner* condition: \(Z_{(18)}=2.682\ p=0.007\), *Stressed dog* condition: \(Z_{(13)}=2.253\ p=0.024\)). In the *Non-stressed owner* condition, however, there was no change (\(Z_{(17)}=1.261 p=0.207\).
The finding that dogs’ working memory performance varied as a function of the manipulation in Phase 2 was further supported by the analysis of the difference between pre- and post-manipulation measures. That is, the number of errors changed differently in the three conditions (Kruskal Wallis test $\chi^2(2)=10.641 \ p=0.0049$; pairwise comparisons with Bonferroni correction: Stressed owner vs. Non-stressed owner: $p<0.05$; Stressed dog vs. Non-stressed owner: $p<0.05$). Dogs in the Stressed conditions showed an improved memory performance (Figure 6).

There is a negative correlation between the change in number of errors and the change in the owners’ stress level (Spearman’s rank correlation test, $r_{(35)}=-0.483 \ p=0.002$) which suggest that dogs’ performance was affected by their owners’ affective states. It is also worth mentioning that dogs’ change in memory performance also correlated with the relative time spent with playing ($r_{(35)}=0.439 \ p=0.007$), dogs whose owners tended to play more with them during the manipulation phase committed more errors when re-tested in the memory task (Phase 3).

Dogs’ better performance in the two Stressed conditions cannot be explained by the owners’ more explicit encouragement, because the number of (verbal) encouragements did not differ between the pre- and post-manipulation phases (Phase 1 vs. Phase 3, Wilcoxon Matched-Pairs Ranks tests, Stressed dog condition: $Z_{(14)}=29 \ p=0.21$; Stressed owner condition: $Z_{(18)}=-1.122 \ p=0.262$; Non-stressed owner condition: $Z_{(17)}=-0.855 \ p=0.393$). Moreover there is no significant differences between the three groups (Kruskall Wallis test, before the manipulation: $\chi^2(2)=1.56 \ p=0.46$ after the manipulation: $\chi^2(2)=3.08 \ p=0.21$).

In addition, we analyzed whether previous training experience influenced dogs’ memory performance. We compared the performance of dogs that had received some sort of official training (33) with those that had not (19), and found no difference either before (Mann-Whitney test $U_{(51)}=259.5 \ p=0.302$) or after ($U_{(51)}=285.5 \ p=0.592$) the manipulation.
The change in performance was not affected by previous training either ($U_{(51)}=268.5$ $p=0.389$).

4. Discussion

In the current study we aimed to investigate the emotional contagion between dogs and owners and examined whether dogs show some sign of taking over their owners’ affective state in a case where only the owner’s affective state was manipulated. We also investigated whether the effects of this kind of contagion of an emotional state (increased level of stress) transfer to a different domain by affecting an aspect of cognitive performance as well. It has been shown that stress and stress hormones influence cognitive performance following an inverse U shape dose-response relationship in both humans (Belanoff et al. 2001) and nonhuman animals (Roozendaal 2000; Salehi et al. 2010), so low to moderate levels of distress have an improving effect on cognitive functions (Shors et al. 1989). Psychological stress can also cause physiological changes (Chida & Hamer 2008) and it mainly affects the hippocampus, the area of the declarative memory (Diamond et al. 1994). Our results are in line with this notion. The analyses of our data allow us to conclude that the owners' state anxiety was effectively manipulated by the experimenter (i.e. after having received negative feedback, owners achieved higher state anxiety scores). The owners' performance in the declarative memory task also seems to be affected by their anxiety level, leading to a better performance in the Stressed owner condition and findings from the Stressed dog condition indicate a similar effect of anxiety on dogs’ spatial working memory. Moreover, dogs’ working memory performance significantly correlated with the change in the owners’ self-reported stress level and changed in the same direction as the owners’ memory performance. This raises the possibility that their owners’ state anxiety is contagious to dogs.
and the emotional contagion can be tracked by measuring changes in dogs’ memory performance.

It is important to note that owners’ improved performance in a stressful situation could not only be generated by the moderately increased stress level; but could also be facilitated by the procedure, by the method of the manipulation. Namely, negative verbal feedback in a skill performance situation can be regarded as a kind of failure, and this can inspire people to perform better in the next task independent of the increased level of stress that negative feedback supposedly elicits. However, the literature also provides evidence suggesting that feelings of failure, when losing a competition, can cause stress hormone release (Bhatnagar & Vining 2003), therefore it may not be possible to disentangle these two seemingly different effects. Moreover, perceiving a situation more or less stressful depends on personality as well (Wirth et al 2006).

One possible alternative explanation of our results could be based on the discrepancy in the difficulty of the initial task. That is, owners performed more poorly in the baseline phase of the Stressed owner condition because they had a more difficult text to read and therefore they had more room for improvement by the end of the experiment. However, this is not likely since there was no main effect of condition on the memory performance of owners and pairwise analyses also confirm the notion that initial performance did not differ between the two experimental conditions. The declining memory performance in the Non-stressed owner condition can be best explained by fatigue, because participants had to read and learn a lot and solve several tasks during the long time of the experiment. On the other hand they probably did not feel any motivation to perform better at the end of the experiment.

Another factor that could have influenced the success of the manipulation is the dogs’ level of training. It could be argued that since we expected the transmission of affective state to happen – at least partly – during an obedience task, dogs that had gone through obedience
training might respond differently and may not experience that much stress (or alternatively may be more attuned to the owner and therefore be more sensitive to their signals). However, we have shown that the change in memory performance did not depend on the level of training, therefore this explanation can be ruled out.

A key finding of the present study is that the anxiety experienced by the owner influences their dog’s behaviour and that these effects are manifested in the cognitive domain. We propose that this phenomenon can be best explained by emotion contagion as the dogs’ performance was not directly reliant on the owner’s affective state or behaviour. Dogs had to solve the task on their own, therefore any change in performance had to be the result of previous interactions. Since very similar effects were observed in the memory performance of the owners, it is plausible to assume that the change of affective state was also similar.

The improvement of spatial working memory performance of dogs in the Stressed owner condition was similar to that of the Stressed dog condition. Since there were significant differences in the owners’ play behaviour and the use of positive reinforcement while interacting with their dogs, we may assume that the owners’ affective state was transmitted at least partly through these behaviour signals. Of course dogs could be influenced by other sources of information, for example the owners’ body language (Merola et al. 2012), facial expression (Nagasawa et al. 2011; Racca et al. 2012), emotional valence of the commands (Ruffman & Morris-Trainor 2011), or other unobservable behavioural signals or odour cues (Prehn-Kristensen et al. 2009).

One of the most important questions in the literature on emotional contagion concerns the problem of how these behavioural cues contribute to the transmission of emotions. Taking an interspecies approach to the question can shed some further light on the matter. Non-conscious mimicry of expressions has been suggested to play a key role in intraspecies cases (e.g. Hatfield et al. 1993) during which the emotional expression of one individual is imitated
by the observer, generating a similar feeling in him/her too. However, non-conscious mimicry is unlikely to work properly between individuals of a different species. Therefore it seems a plausible explanation that a more sophisticated perception of the social context contributes to the phenomenon and that it cannot be accounted for by such direct physiological changes. The importance of a higher level of social sensitivity is also in line with findings that show that less social species, such as the red-footed tortoise, are not susceptible to a related phenomenon, contagious yawning (Wilkinson et al. 2011). The dog’s special sensitivity to human behavioural cues, however, can lead to the appearance of emotional contagion between different species and may also serve similar functions as in a human-to-human interaction.

In sum, we showed similar effects in dogs as in their owners with direct manipulation of the owners only, supporting the existence of emotional contagion between two different species. Recent experimental data suggest that dogs’ behaviour can be influenced by the pretended emotion of a human. For example they show an empathic-like response toward a crying human (Custance & Mayer 2012), and react to an unfamiliar object according to the owner’s attitude (Merola et al. 2012). The current study extends our understanding of these results since the change in the memory performance observed in dogs is unlikely to be attributed to any conditioned response to the behavioural cues of the human. Furthermore, this study gives further support for the idea that the real emotions of the owner can influence the dog; and our results suggest that the underlying mechanism may be emotion contagion. This points to the conclusion that it is possible to influence the dog’s stress level via the owner even in an artificial situation. We suggest that these effects are due to the special domestication history of the dog that has endowed this species with a unique sensitivity to the behavioural cues of humans.
Acknowledgements

Financial support was provided by the Hungarian Scientific Research Fund (OTKA K-100695).

Ethical standards

The experiments comply with the current Hungarian laws.

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Figure 1: Experimental arrangement of the dog Spatial Working Memory task. The owner made the dog sit equidistant from the 7 plastic containers serving as hiding places. The positions of the containers are labelled as L(left) 1-3, R(right) 1-3 and M(middle).

Figure 2: Comparison of the owners’ state-anxiety scores obtained from pre- and post-manipulation phases (median, quartiles and extreme values) in the Non-stressed- and Stressed owner conditions. (* p<0.001)

Figure 3: Number of words recalled by the owners in the declarative memory task before and after the manipulation.

Figure 4: Changes in the number of words (pre- vs. post-manipulation phases; median, quartiles and extreme values) recalled by the owners in the declarative memory task. (* p = 0.014)

Figure 5: Number of erroneous choices (pre- vs. post-manipulation phases; median, quartiles and extreme values) by the dogs in the memory task. (* p < 0.05)

Figure 6: Changes in the number of dogs’ erroneous choices in the Spatial Working Memory task (pre- vs. post-manipulation phases; median quartiles and extreme values. (* p=0.0049)
Figure 4

Change in the no. of recalled words

Non-stressed owner

Stressed owner

condition

*
Figure 5

The diagram illustrates the number of erroneous choices across different conditions: Stressed owner, Stressed dog, and Non-stressed owner. The data is compared between pre-manipulation (blue) and post-manipulation (green) conditions.

Significance levels are indicated by asterisks (*) above the bars, denoting statistically significant differences between the two conditions.

The y-axis represents the number of erroneous choices, ranging from 0 to 20.
Figure 6

The box plot shows changes in the number of erroneous choices across different conditions: Stressed owner, Stressed dog, and Non-stressed owner. The plot indicates a significant difference in the number of choices made under stress compared to the non-stressed condition.
AUTHOR DECLARATION TEMPLATE

We wish to confirm that there are no known conflicts of interest associated with this publication and there has been no significant financial support for this work that could have influenced its outcome.

We confirm that the manuscript has been read and approved by all named authors and that there are no other persons who satisfied the criteria for authorship but are not listed. We further confirm that the order of authors listed in the manuscript has been approved by all of us.

We confirm that we have given due consideration to the protection of intellectual property associated with this work and that there are no impediments to publication, including the timing of publication, with respect to intellectual property. In so doing we confirm that we have followed the regulations of our institutions concerning intellectual property.

We further confirm that any aspect of the work covered in this manuscript that has involved either experimental animals or human patients has been conducted with the ethical approval of all relevant bodies and that such approvals are acknowledged within the manuscript.

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