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Can dogs increase children's attention and concentration performance? A randomised controlled trial.

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Many practitioners report that the presence of an animal, or interaction with an animal, increases the attention and concentration of children, elderly persons or patients. Previous studies support this impression via indirect variables, but direct effects on children's attention performance have not yet been measured. We therefore designed a study that used neuropsychological concentration tasks to test the effect of the presence of dogs, and contact with dogs, on children's performance. In a randomised, controlled crossover trial, 24 children between 10-14 years completed a memory task and three neuropsychological attention tests. We also used passive infrared hemoencephalography (PIR HEG) to assess a biological correlate of attention. The children interacted with either a trained therapy dog or the robotic dog AIBO for 15 minutes before they completed the tests. We found that the learning effect in the memory test, as well as in the neuropsychological attention test "Cancellation Screen", was significantly enhanced (p = 0.021) when children were in the presence of, or interacted with the dog. No such effect was found in the two attention tests, "Continuous Performance Test" and "Divided Attention Bimodal". In the presence of the robotic dog, attention processes measured in frontal brain activity, via PIR HEG, were significantly reduced over time during the test "Divided Attention Bimodal" (p < .001). These processes did not decrease in the presence of the real dog. We found no such difference during the two other attention tests. Moreover, the PIR HEG signal was significantly higher in general in all three attention tests in the presence of the dog. We conclude that interacting with a dog, or the presence of a dog, may increase children's attention and concentration performance.

*Key words***:** attention, concentration, children, dog, human-animal interaction

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Introduction

Many teachers believe that introducing an animal into the classroom may improve their students' attention to the environment, and such claims are common in the literature (Beetz, 2012; Levinson, 1997; Prothmann, 2008). More and more teachers favour taking their dogs or other pets to school and integrating them into their lessons. Recent surveys from Germany highlight this increase in "school dogs", and there is a similar trend across the German-speaking part of Europe (Agsten, 2009; Mars, 2012; Volk, 2007). Parents, school principals, and politicians sometimes worry that a dog in a classroom will distract students, but teachers argue that contact with animals, and dogs in particular, stimulates children's attention and concentration at school.

A range of studies have sought to determine if human-animal interactions have positive or negative effects on human behaviour, and if they support learning, attention or concentration. Kotrschal and Ortbauer (2003) found that overt activity, withdrawal and aggressive interactions decreased among children when there was a dog in the classroom. The presence of a dog also enhanced group activities and improved social interaction. Children paid more attention to the teacher when the dog was present. The authors concluded, "the presence of a dog in a classroom could positively stimulate social cohesion in children and provide a relatively cheap and easy means of improving teaching conditions" (Kotrschal & Ortbauer, 2003, p. 147). In another study, eight children with Down's syndrome were more responsive to adults in the presence of a live dog than of a toy dog, and also directed more attention to the real dog (Limond, Bradshaw, & Cormack, 1997).

A series of studies by Gee and colleagues found that children's performance improved for different tasks when a dog was present; they took this as an indicator of improved concentration (Gee, Christ, & Carr, 2010a; Gee, Church, & Altobelli, 2010b; Gee, Harris, & Johnson, 2007; Gee, Sherlock, Bennett, & Harris, 2009). In a motor skill task, both developmentally delayed and normally developing children performed tasks more quickly, and maintained their accuracy, when a dog accompanied them (Gee et al., 2007). Pre-schoolers with and without language impairments adhered better to instructions for an imitation task when a dog was present than they did in the presence of a human or a toy dog (Gee et al., 2009). Children needed fewer prompts in a memory task when a dog was present, and more prompts when another human was present (Gee et al., 2010a). And preschool children made fewer errors, like irrelevant choices, in a match-to-sample task when a dog was present than when a human or a toy dog was present (Gee et al., 2010b). Finally, Prothmann (2008) found that the self-rating of children in a psychiatric facility improved significant after a half-hour interaction with a dog; they thought themselves more attentive, alert, and better adjusted.

We know of only one study so far that has used direct measures to test if interacting with dogs can increase human attention and concentration, and it found no effect. However, it was limited in design and the results cannot be generalized (Prothmann, 2008).

The literature describes several biological and psychological mechanisms that suggest how the presence of, and contact with a dog, may enhance attention and concentration. We briefly mention here only a few, and reserve more detailed description of possible mechanisms for our discussion. First, the well-documented stress-reducing effect that dogs have on humans has been measured using cardiovascular parameters (Levine et al., 2013), cortisol levels (Beetz et al., 2011; Odendaal & Meintjes, 2003), and perceived fear and anxiety (Barker, Pandurangi, & Best, 2003; Shiloh, Sorek, & Terkel, 2003). Reduced stress may improve memory, attention, and concentration performance, since stress is known to hinder these processes (Howland & Wang, 2008; Kim, Song, & Kosten, 2006). Second, attention and concentration deficits correlate with alterations in domapinergic systems, as well as deficits in prefrontal cortex functions (Biederman, 2005; Genro, Kieling, Rohde, & Hutz, 2010). This potential mechanism is indicated by a preliminary finding that dopamine in humans significantly increased after they interacted with a dog (Odendaal & Meintjes, 2003). Third, the presence of an animal may stimulate intrinsic motivation to learn and increase curiosity and attention (Beetz, 2012). Perceptions of other people and one's surroundings may also be more positive in the presence of a dog (Wells & Perrine, 2001), and this may facilitate learning. In light of the variety of possible mechanisms by which dogs may reduce stress, we decided to measure attention and concentration performance by using psychological measures and a corresponding biological parameter that reflects prefrontal activity in our study design. In studies with children and adults who suffer from attention-deficit hyperactivity disorder it was found that reduced activation in the prefrontal cortex reflects attention process deficits (Cubillo, Halari, Smith, Taylor, & Rubia, 2012; Dickstein, Bannon, Castellanos, & Milham, 2006). Therefore, measuring a correlate of prefrontal brain activity may offer new insights into the possible attention-enhancing effects of a dog.

Our goal was to examine the effects that the presence of, and contact with a dog, had on children's performance of a memory task and neuropsychological concentration tasks, and to visualize the effects with passive infrared hemoencephalography. We thus designed a randomised, controlled trial with a non-clinical sample, and systematically used direct measures of attention and concentration performance.

Methods

Participants

We recruited 24 children, between 10-14 years old (M = 11.34, SD ± 0.95), from public schools in Wollerau and Samstagern, Switzerland: 13 were boys and 11 were girls. All children were Swiss nationals. We chose a non-clinical sample, and included only children who had not been diagnosed with attention deficits. We also excluded children with learning deficits, health problems, children who were on medication, children who had allergic reactions to dogs or fear of dogs, or who had ever owned a dog, and children who were not willing to take part spontaneously. We excluded children with health problems and medication to reduce possible effects on the biological parameter measured via PIR HEG, as well as effects on memory and attention performance. Excluding children who owned a dog at home controlled for differences between children who have constant contact with dogs and those who don't. We obtained written informed consent from parents and from children 14 and up. The ethics committee of northern and central Switzerland approved this study.

Measures

Memory

Memory capacity was assessed via the subtest "Digit Span", from the intelligence test HAWIK-IV (WISC; Petermann &

Petermann, 2007). In this subtest, children listen to a sequence of numbers and repeat them (forward in the first part of the task, and backwards in the second part). The test requires recording and recalling information, as well as processes of attention and working memory. The test has been broadly used and has satisfactory internal consistency and validity.

Attention and concentration

We used a standardized neuropsychological test to assess attention and concentration performance. Candit (http://www.candit.com) developed the computer-based test, in cooperation with the Institute of Neuropsychology at the University of Zurich, Switzerland. We used three subtests. In the first, ("Cancellation Screen"), subjects had to cancel certain stimuli (distinguishing apricots and pears from other fruit) for eight minutes. This subtest measured unbroken concentration while completing a monotonous task. We computed the mean of right answers, omissions, and errors to assess attention performance. In the second subtest ("Continuous Performance Test"), subjects monitored sequences of visual pictures at a predetermined tempo for five minutes. The task was to react only to a certain combination of pictures that appears periodically. This test measured the extent of impulse or behaviour control, as well as attention. As indicators of performance, we calculated the number of right answers and answers that were given too soon or supplemented. The third subtest ("Divided Attention Bimodal") measured shared attention. Subjects reacted to visual and auditory stimuli simultaneously for 3.5 minutes. As indicators of performance, we calculated numbers of right answers (hits), false positive and negative alarms, and reaction time. The indicators of performance in the three subtests show satisfactory internal consistency and validity (Candit, 2001). Stimuli were presented on a 17" screen, about 80 centimetres in front of the face of the child sitting in a chair. Either the computer mouse or two buttons (highlighted red and green) could be used to provide answers.

Correlate of frontal brain activity

We used passive infrared hemoencephalography (PIR HEG) to assess a correlate of frontal brain activity. Activity in the prefrontal cortex is a neural correlate of executive functions like attention processes (Cubillo et al., 2012; Dickstein et al., 2006). To measure attention and concentration processes, brain activity in this brain region must be captured. PIR HEG is a technique that indirectly measures brain activity via thermal emission from the forehead (Carmen, 2004). The hypothesis underlying the technique is that changes in thermal emission reflect changes in neuronal activity: the higher the emitted heat, the higher the activation of the brain cells. The method was designed to train people to control cerebrovascular activity via thermal biofeedback and was intended to increase their prefrontal cortical brain activity. The PIR HEG signal reflects a combination of thermal activity generated by brain cell activity, vascular supply, and vascular return. The method is free from eye roll and surface electromyogram artefacts. Emitted heat is measured via three infrared sensors in a frontlet that is fixed on the forehead. The system captures infrared radiation within the 7-14 micron band, has a thermal resolution of .01 degrees Fahrenheit, and a data sampling rate of 60 times per second (Carmen, 2004).

Mood

Children's mood was assessed by self-report via a "visual analogue scale" (VAS). We assessed the dimensions 'calmness,' 'attention,' 'alertness,' 'strength,' 'slowness,' 'satisfaction,' and 'interest' using semantic differentials as in Turner and colleagues (2003). Children were asked to put a cross on a line between two antonyms to represent their mood.

Additional questionnaire

The children filled out an additional 9-item questionnaire designed for this study to assess subjectively perceived support, and their preference for one of the two conditions. The questionnaire also controls for animal contact at home and the child's attitude towards dogs. Items were answered with 'exactly true', 'true', 'a bit true', 'not true', or 'not at all true'. The questionnaire yielded scores of 0-5, with higher agreement on lower scores.

Design and procedures

The study was designed as a randomised, controlled crossover trial. All children took part in two experimental sessions in two consecutive weeks. The children were randomly assigned to either the experimental or the control condition for the first session, and reassigned to the reverse condition for the consecutive session. Sessions were held between 13:00 and 18:00. Each child completed both sessions at the same time of day to control for daytime effects. The children were blinded to the aim of the study. We used the following cover story to explain the process to the children: A person had to supervise the experimenter. This person needed to bring her dog to the session because it was afraid of staying alone at home. We asked the children if they wanted to play with the dog while they waited for the tests to start.

Day 1

In the first session, the children filled out the first of three VASs. Then they waited for 15 minutes, during which time they could interact either with the dog or AIBO, depending on the condition to which they were assigned. Next, the PIR HEG was placed on the children's foreheads and they filled out the second VAS for the three-minute waiting phase in which the sensors of the PIR HEG were evened out. Then the children completed the memory task and the three neuropsychological attention tests.

Afterwards, the PIR HEG was removed and the children filled out the third VAS. The whole session lasted about an hour.

Day 2

In the second session, a week later, the children went through the same procedure under the other condition. They then filled out the additional questionnaire that measured the experienced support. All children received a final debriefing. Room temperature was the same during all sessions to minimize artefacts in the PIR HEG recording. We limited the children's interactions with the dog to quiet activities. Excessive physical activity, like running, was forbidden because it leads to enhanced blood flow.

Conditions

Dog condition

In the dog condition, the children were free to interact with the dog as they wished within a range of quiet activities. They stroked the dog, brushed its hair, cuddled up or carried out small tasks like giving it commands (e.g., sit, lay down, roll over etc.). The dog was a female trained black Labrador Retriever and an experienced therapy dog. The dog was present during the whole session, and slept/rested beside the children's chairs while they completed the tasks. The dog's owner was present at all times for safety reasons, and so that the dog remained comfortable. The owner avoided interaction with the children unless it was necessary. The dog was free to decline to interact with the children at any time and did not attend more than two sessions in a row. The dog could rest or run free outside between the sessions. The dog's owner was responsible at all times for both the dog's and the children's security. Ethical clearance was obtained from the cantonal animal ethics board. The study follows the guidelines and declarations of the International Association of Human-Animal-Interaction Organisations (IAHAIO), specifically the Prague-declaration.

Control condition

The children played with the robotic dog AIBO (ERS-210, Sony Inc.) as a control condition. This robotic dog interacts with humans and displays the emotions 'joy', 'sadness', 'anger', 'astonishment', 'fear' and 'aversion'. It asks for stroking or playing, is programmed to react to a pink ball and obeys commands. The experimenter explained to the children how to interact with AIBO, and the children received a list of commands it would obey. To control for the effect of the dog owner's presence, there was an additional person present in this condition.

Statistical analysis

We analysed the data with SPSS, version 19.0. A priori sample size calculation and effect-size calculation were conducted with G*Power, version 3.1. Analysis of PIR HEG data was executed with EViews, version 6. As a first step, we tested data for normal distribution with the Kolmogorov-Smirnov test and QQ-Plots. We tested also homogeneity of variance using the Levene test. Non-parametric tests were used if the outcomes were not normally distributed. In case of violation of sphericity, we used a Greenhouse-Geisser correction. A p-value ≤ 0.05 was accepted as statistically significant.

All subjects completed data collection and were included in statistical analysis. The data of a few children were missing in some subtests, mainly due to technical problems. Accordingly, results were calculated with a lower *N* (as indicated in the tables).

Results of the questionnaire were analysed using t-tests for dependent samples. Cohen's d was computed as effect size (Cohen, 1988). VAS data were analysed using a two-way ANOVA with repeated measurements. As effect size, η^2_{part} was calculated. Data from neuropsychological tests were analysed according to Senn (2002). We then performed t-tests for independent samples (or the corresponding non-parametric Wilcoxon test with an approximated φ as effect size) within the two groups, with

Table 1. Number of remembered items in the subtest "Digit Span."

Group	Time	*M*	*SD*	*n*	t-Test
Starts with dog	T1	14.17	3.54	12	*p* = .078
	T2	15.33	3.45	12	
Starts with AIBO	T1	13.92	2.54	12	*p* = .021
	T2	15.67	4.16	12	

Note: M: Mean, *SD*: Standard deviation, *n*: number of cases, AIBO: robotic dog (ERS-210, Sony Inc.)

opposite order of condition. PIR HEG data were analysed within phases during which the attention tests were actually carried out, for each subtest separately. First, data was smoothed using the Hodrick-Prescott filter. Second, beta coefficients were computed using ordinary least square regression estimates. Finally, we used linear mixed effect models to estimate the impact of the presence of the dog on thermal emission. Time was included as categorical fixed effect and individuals as random effect to account for the dependency among the repeated observations within participants.

Results

Memory

We found no general effect of the presence or absence of the dog or AIBO for memory performance, but a significant learning effect ($t(22) = 3.29$, $p = .003$, $d = 1.34$) in the subtest "Digit Span" from the intelligence test HAWIK. In the second session, children performed better and remembered 2.9 items more, independent of the presence of the dog or AIBO. To look more deeply into the data, a t-test for independent samples was performed for each of the two groups with different condition orders (see table 1). There was only a significant increase in performance if the dog was present during the second session ($t(11) = 2.68$, $p = .021$, $d = 0.51$). No performance gain was found when AIBO was present in the second session ($t(11) = -1.94$, $p = .078$, $d = 0.33$).

Attention and concentration

Cancellation Screen

For the subtest "Cancellation Screen", we found that the presence of the dog or AIBO did not influence the mean of correct answers or errors. However, there was a significant overall learning effect for the omission rate ($t(20) = -3.12$, $p = .005$, $d = 1.33$). The estimated effect reveals that, in the second session, the children omitted 0.13 fewer items than in the first session, independent of the presence of the dog or AIBO. We performed independent *t*-tests to investigate the dog-specific influence of the learning effect. The presence of the dog in the second session reduced the omission rate significantly ($t(10) = -2.73$, $p = .021$, $d = 1.13$). In contrast, children who interacted with the dog in the first session did not have a significantly reduced

Table 2. Mean omission rate during the "Cancellation Screen."

Group	Time	*M*	*SD*	*n*	t-Test
Starts with dog	T1	0.25	0.21	11	*p* = .127
	T2	0.15	0.13	11	
Starts with AIBO	T1	0.27	0.18	11	*p* = .021
	T2	0.11	0.11	11	

Note: M: Mean, SD: Standard deviation, *n*: number of cases, AIBO: robotic dog (ERS-210, Sony Inc.)

Table 3. Reaction time in the test "Divided Attention Bimodal."

Group	**Time**	***M***	***SD***	***n***	**t-Test**
Starts with dog	T1	0.54	0.06	11	*p* = .050
	T2	0.52	0.05	11	
Starts with AIBO	T1	0.51	0.05	12	*p* = .211
	T2	0.50	0.06	12	

Note: M: Mean, SD: Standard deviation, *n*: number of cases, AIBO: robotic dog (ERS-210, Sony Inc.)

omission rate in the second session, in the presence of AIBO ($t(10) = 1.67$, $p = .127$, $d = 0.55$).

Continuous Performance Test

We found that the presence of the dog or AIBO did not influence either the number of correct answers or the answers that were given too soon or supplemented in the subtest CPT (number of correct answers: starting with dog ($t(10) = 1.32$, $p = .216$, $d = 0.42$; starting with AIBO ($t(11) = 0.00$, $p = 1.000$, $d = 0.00$ / answers given too soon: starting with dog ($Z = 0.00$, $p = 1.000$, $\varphi = 0.00$; starting with AIBO ($Z = 0.00$, $p = 1.000$, $\varphi = 0.00$) / answers given supplemented: starting with dog ($t(10) = 0.00$, $p = 1.000$, $d = 0.00$; starting with AIBO ($t(11) = -0.92$, $p = .379$, $d = 0.30$)). There was no learning effect from session one to two ($t(21) = -1.05$, $p = .307$, $d = 0.44$).

Divided Attention Bimodal

The same pattern of results was found for the "Divided Attention Bimodal" in terms of numbers of correct answers, false positive and false negative alarms (Table 3). However, we found the presence of the dog or AIBO had a different influence on reaction time: The presence of AIBO in the second session significantly enhanced reaction time ($t(10) = 2.23$, $p = .050$, $d = 0.28$). Children that worked in the presence of the dog in the second session showed no such significant increase ($t(11) = -1.33$, $p = .211$, $d = 0.20$).

Correlate of frontal brain activity

Results of the passive infrared hemoencephalography are presented separately for each subtest.

Figure 1. PIR HEG during the test "Cancellation Screen."

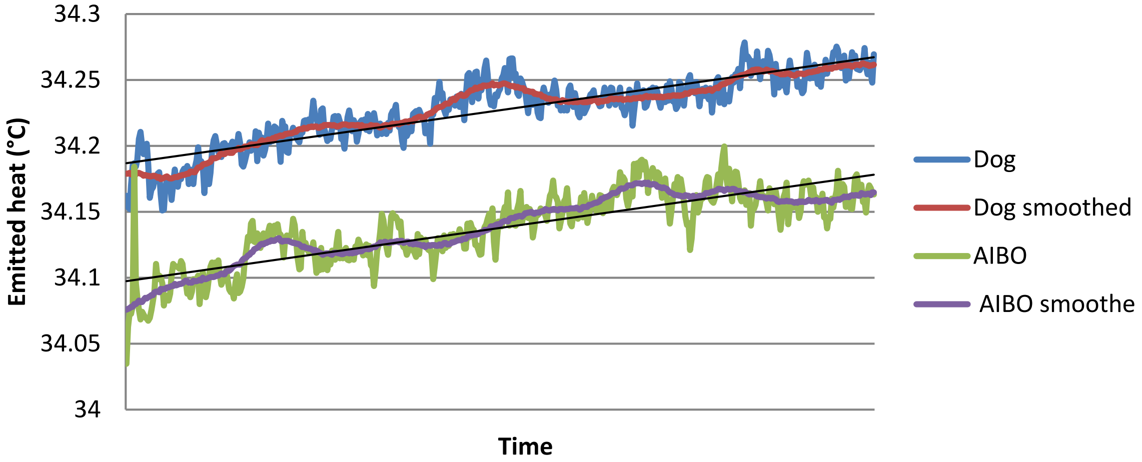
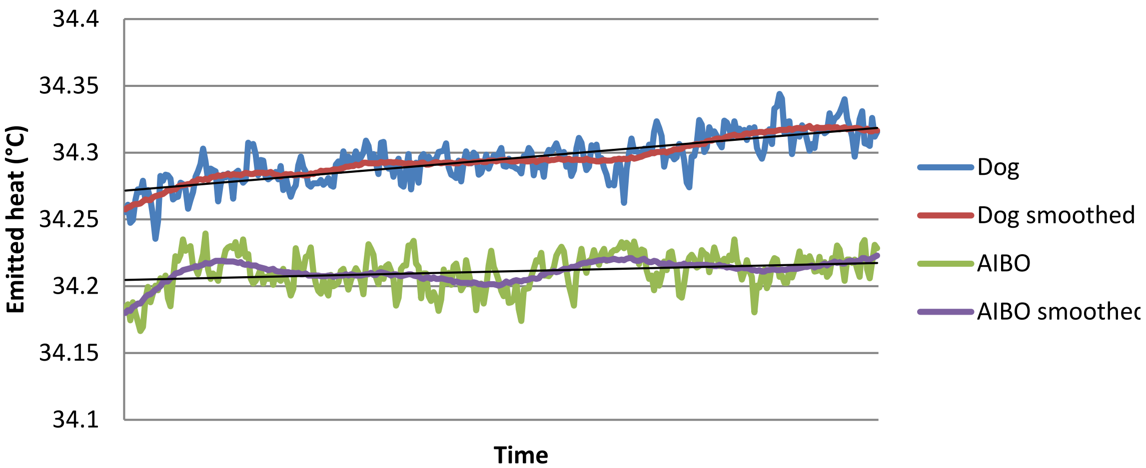


Figure 2. PIR HEG during the test "Continuous Performance Test."



Cancellation Screen

Measured emitted heat increased significantly during the course of this first subtest of the neuropsychological attention test in the presence of the dog and in the presence of AIBO as the computed beta coefficients show (dog condition: β = 0.002, p < .001; AIBO condition: β = 0.002, p < .001) (see figure 1). Results of the linear mixed effect models revealed a significant mean difference in temperature of 0.04 °C (95% CI 0.03 - 0.05, p < 0.001). When the dog was present, heat output was higher than when AIBO was present.

Continuous Performance Test

Again, heat emission increased in the presence of the dog and in the presence of AIBO during the "Continuous Performance Test" (dog condition: β = 0.002, p < .001; AIBO condition: β = 0.000, p < .001) as shown by the averaged curve in figure 2.

Results of the linear mixed effect models revealed also a significant mean difference in temperature of 0.08 °C (95%CI 0.08 - 0.09, p < 0.001) with a higher heat output in the presence of the dog.

Figure 3. PIR HEG during the test "Divided Attention Bimodal."

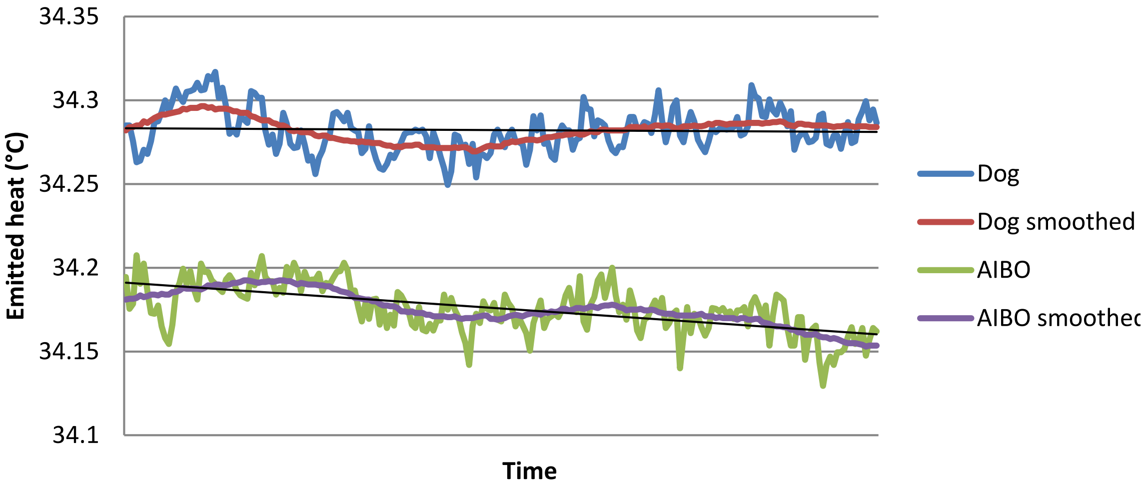


Table 4. Children's answers to the questions "the dog supported me" and "AIBO supported me."

Answer	**Subjective felt support**	
	Dog	AIBO
Exactly true	16.7%	16.7%
True	50.0%	20.8%
A bit true	29.2%	54.2%
Not true	4.2%	8.3%
Not at all true	-	-
Total	100%	100%

Divided Attention Bimodal

Beta coefficients revealed a significantly reduced heat emission over time in the presence of AIBO ($\beta = -0.002$, $p < .001$). In contrast, emission stayed constant in the presence of the dog ($\beta = -0.000$, $p = .132$) (Figure 3). Again, results of the linear mixed effect models revealed a significant mean difference in temperature of 0.11 °C (95% CI 0.10 - 0.12, $p < .001$). When the dog was present, heat output was higher than when AIBO was present.

Mood

In the analysis of moods, we found no significant variance of the VAS in terms of subjective experience of 'calmness', level of 'attention' or 'strength'. The dimension of perceived 'alertness' did change significant over time ($F(2, 44) = 7.21$, $p = .002$, $\eta^2 = 0.25$). Alertness was greater after both interaction phases than at the beginning or the end of each session. For 'satisfaction' there was also a significant effect over time ($F(2, 44) = 3.99$, $p = .026$, $\eta^2 = 0.15$) as well as for 'interest' ($F(1.55, 34.04) = 5.39$, $p = .015$, $\eta^2 = 0.20$). Children felt more satisfied after the interaction phase, and at the end of each session. They reported an increase in interest after the interaction phases and a decrease at the end of each session, independent of the presence of the dog or AIBO.

The dimension 'slowness' revealed a significant interaction effect ($F(2, 44) = 6.89$, $p = .002$, $\eta^2 = 0.24$). To specify this effect, we performed t-tests for dependent samples for each time point during the sessions. Children felt significantly less 'slow' after they interacted with the dog than after they interacted with AIBO ($t(23) = 2.79$, $p = .011$, $d = 0.85$).

Additional Questionnaire

The children experienced significantly greater subjective support from the dog than from AIBO while completing their tasks ($t(23) = -2.15$, $p = .043$, $d = 0.40$). Of the children, 66.6% stated that they perceived substantial support from the dog. Only 37.5% of the children experienced the same amount of support from AIBO (see table 4).

The company of the dog would have been preferred by 91.7% of the children on both days. In contrast, only 8.3% of the children would have preferred AIBO for both days. None of the children owned a dog, since this was an exclusion criterion. However, 95.8% of the children stated that they like dogs, 4.2% had a neutral attitude and none expressed a dislike for dogs. Exactly half the children owned a companion animal (rabbits, guinea-pigs, mice and/or fish). Gender had no influence on answers to the questionnaire.

Discussion

We analyzed the effects the presence of, and contact with a dog, had on children's performance of a memory task and of three neuropsychological concentration tasks, and visualized these effects with passive infrared hemoencephalography.

In the memory task, we found performance increased significantly when the dog was present during the second session. No such performance gain was found when AIBO was present in the second session. The result was the same for the first concentration task, "Cancellation Screen". The presence of the dog in the second session reduced the omission rate significantly. Children who interacted with the dog in the first session did not have a significantly reduced omission rate in the second session when AIBO was present. In the second task, the "Continuous Performance Test", the presence of the dog did not change the quality of performance. In the third task, the "Divided Attention Bimodal", the presence of the dog did not affect the number of correct answers, false positive, or false negative alarms. But the presence of AIBO in the second session significantly enhanced reaction time. In the second session, children who worked in the presence of the dog showed no such significant increase.

Furthermore, with PIR HEG, we found a significant gain in heat emission (which indicates higher brain activity in the frontal lobe) in the two first subtests of the neuropsychological attention test in the presence of the dog and in the presence of AIBO. During the last subtest, when AIBO was present, we found heat emission was significantly reduced over time. In contrast, emission stayed constant when the dog was present. Emitted heat was constantly higher in all three neuropsychological subtests in the presence of the dog than in the presence of the AIBO.

When we measured mood, we found no significant variance of the VAS in terms of subjective experience of 'calmness', level of 'attention' or 'strength'. The dimension of perceived 'alertness', 'satisfaction' and 'interest' did change significantly over time, independent of the presence or absence of the dog or AIBO. However, children felt significantly less 'slow' after they interacted with the dog than after they interacted with AIBO.

The questionnaire revealed that children completing their tasks experienced significantly greater subjective support from the dog than from AIBO. Furthermore, 91.7% of the children would have preferred the company of the dog on both days.

Interpretation of the results

The learning effect in a memory test and in one of three neuropsychological attention tests was enhanced after children interacted with a dog or were in the presence of a dog. We found that attention performance, measured by frontal brain activity via PIR HEG, did not decrease over time in the presence of a real dog, but did decrease in the presence of the robotic dog, AIBO. Moreover, the PIR HEG signal was constantly higher in the presence of the dog.

These findings have two broad implications. First, therapy dogs are not a distractor. Performance did not decrease when the dog lay at the children's feet while they completed the tests, even though the dog sometimes moved a little, or snored loudly. Other studies have also found that quality of performance across a broad variety of tasks did not decrease in the presence of a dog (Allen, 2003; Allen, Blascovich, Tomaka, & Kelsey, 1991; Gee et al., 2010a; Gee et al., 2010b; Gee et al., 2007; Gee et al., 2009; Prothmann, 2008).

Second, interacting with a dog, and the presence of a dog, can increase children's attention and concentration performance on tests, as well as physiologically. These results are consistent with previous research. We mentioned in the introduction studies that addressed the indirect attention-enhancing effects of companion dogs (Gee et al., 2010a; Gee et al., 2010b; Gee et al., 2007; Gee et al., 2009; Kotrschal & Ortbauer, 2003; Limond et al., 1997).

These findings have implications for school dog projects. Together with previous findings, they show that integrating a dog into lessons can enhance children's attention and concentration. The children may then be better able to concentrate on learning, instead of focusing on paying attention. These data suggest that a dog in a classroom will not distract students.

We tested healthy children without known learning problems, so it can be argued that animal-assisted interventions with school dogs may be helpful for a majority of children, and not only for children with special needs. It may not be necessary to own a dog, or to already have a relationship to a dog, to profit from a dog's presence in the classroom. School-aged children who do not have a dog at home can benefit from the attention-enhancing effect of interacting with a dog at school.

It is not clear why we found an increased learning effect only in the memory task, and the first of the three neuropsychological attention tests. Performing well on the tasks in the study required using different kinds of attention processes, which increased in complexity. Dogs may influence different kinds of attention processes in different ways, so the effect may be seen only in select attention processes. We have, as yet, no data to support this hypothesis, and suggest it be tested in future studies. The presence of a dog may also have a time-limited effect. The dog may affect attention and concentration processes only when it is still a novelty, or when children do not face the challenge of concentrating beyond 15 minutes of exhausting tasks.

The results of the PIR HEG, however, suggest that the attention-enhancing effect endures over time. Under both conditions, the frontal brain activity of the children increased at first. But in the presence of AIBO, their frontal brain activity declined in the last and most challenging task. In contrast, in the presence of the dog the children's frontal activity remained stable. This indicates that the dog has a continued effect on attention and concentration processes for at least up to 50 minutes after the interaction phase, and also has an effect on more complex processes. Regardless of the development of the frontal brain activity during the attention tests, the amount of emitted heat was constantly higher in the presence of the dog. This indicates that interacting with, and the presence of a dog influences both the intensity and the changes of attention processes over time.

The children had increased reaction time when AIBO was present in the second session, and this needs further investigation. The ability to make a quick answer can be useful, but quick answers may also increase the likelihood of errors (Johnson & Proctor, 2004). We believe that the stress-reducing effect of the dog prevented the increase of speed that would normally have occurred in the second session. The presence of the real dog may have relaxed the children, allowing them to reflect and give answers at a more measured pace.

We found that the significant influence of a dog was dependent of the order of the sessions. The dog increased learning from one session to another if it was present during the second session. In the presence of the dog, children profited more from repeating the task. But the dog had no overall effect. In the first session children might have been more excited because they did not know what to expect. This might have reduced their attention performance, resulting in the dog having no general effect. Or the presence of the dog during the first session may already have enhanced children's performance (although not to a statistically significant degree). This might have prevented a significant performance gain in the second session when AIBO was present. In the PIR HEG, however, we found attention was enhanced, independent of the session order. We suggest testing these mechanisms in further studies.

On the visual analogue scale, children were not calmer or more relaxed. On the contrary, the children said that they felt they could respond significantly faster after having interacted with the dog than with AIBO. At first glance, these findings contradict Prothmann's (2008). In Prothmann's study, children in a psychiatric facility rated themselves as significantly more attentive, alert, well adjusted, and better tempered after interacting with a dog for thirty minutes. Prothmann investigated a clinical sample. The children in our non-clinical sample may have been less excited and tense, and so the dog may not have influenced their calmness. If we interpret perceived increased speed and alertness as aspects of the same phenomenon, then an activating effect that corresponds with Prothmann's findings is evident.

Possible mechanisms

Several possible mechanisms may enhance attention. Here, we will briefly list the mechanisms described in the literature and suggest further investigations on all of these hypotheses.

In our study, we saw for the first time attention enhancing effects on a physiological level. This supports the hypothesis that physiological changes, triggered by interaction with a dog, may play a key role. Possible factors might include dopamine, the stress-reducing effect of dogs, and oxytocin. Dopamine is known to enhance concentration and attention (Genro et al., 2010), and one study found a significant increase in dopamine in humans after they interacted with a dog (Odendaal & Meintjes, 2003).

Stress hinders learning (Howland & Wang, 2008; Kim et al., 2006; Wolf, Bauser, & Daum, 2011). The well-documented stress-reducing effects of dogs might therefore explain why learning is enhanced in a dog's presence. Interacting with dogs reduces human cortisol levels in stressful situations (Barker, Knisely, McCain, & Best, 2005; Barker, Knisely, McCain, Schubert, & Pandurangi, 2010; Beetz et al., 2011; Friedmann & Son, 2009; Odendaal & Meintjes, 2003). This may be a direct mechanism, since cortisol has dose dependent negative effects on memory and attention processes (Het, Ramlow, & Wolf, 2005; Vedhara, Hyde, Gilchrist, Tytherleigh, & Plummer, 2000). Interacting with dogs also improves cardiovascular parameters (Allen, Blascovich, & Mendes, 2002; DeMello, 1999; Friedmann & Son, 2009; Grossberg & Alf, 1985; Levine et al., 2013; Nagengast, Baun, Megel, & Leibowitz, 1997). The resulting physical calmness may improve memory and attention processes.

It has also been hypothesized that oxytocin is an underlying mechanism in this process, inhibiting stress-systems and providing a direct calming effect that improves capacity and receptiveness (Beetz, Uvnäs-Moberg, Julius, & Kotrschal, 2012; Julius, Beetz, Kotrschal, Turner, & Uvnäs-Moberg, 2013; Uvnäs-Moberg, 2003).

Given the results of the questionnaire that we used, we also believe that psychological mechanisms play an important role. The presence of an animal may stimulate a child's intrinsic motivation to learn and increase their curiosity and attention. This effect may not be limited to learning directly about the animal in their presence, but also apply to learning and performing tasks (Beetz, 2012). We also found that children's motivation was higher when the dog was present than when AIBO was present. The children's answers reflect this, since most of them would have preferred to interact with the dog twice instead of interacting with AIBO twice. The same preference was noted amongst kindergarten children in a previous study with AIBO (Ribi, Yokoyama, & Turner, 2008).

The dog's presence may change the atmosphere for children; the fact that they felt comfortable in the presence of the dog supports this notion. Previous results suggest that dogs influence human perception of surroundings (Friedmann, Katcher, Thomas, Lynch, & Messent, 1983; Kruger & Serpell, 2006). People look happier and more relaxed in a picture if they are accompanied by a dog (Lockwood, 1983; Rossbach & Wilson, 1992; Wells & Perrine, 2001). In the presence of a dog, children might have trusted the investigator more and felt more comfortable during the course of the experiment. Even the tests and the room itself might have appeared less threatening in the presence of the dog, since rooms are perceived as more pleasant when a dog is in them (Wells & Perrine, 2001). Such a more positive atmosphere can facilitate learning. Finally, the children in this study felt significantly more supported by the dog than by AIBO, which may have also positively influenced the children's memory, attention and concentration performance.

Limitations

The present study provides promising new findings that are in line with previous results, but there are limitations to consider. The main limitation of the study is the relatively small sample size. The study should be replicated with larger samples and with different populations. We tested healthy children between ages

10 and 14, so our results cannot be generalized to other populations.

We were further limited by potential reliability problems in the error indices in the attention tests. The tasks are relatively simple, and errors are rare even when the test-taker is pressed for time (Büttner & Schmidt-Atzert, 2004). If a child makes a lot of errors, it is hard to discern the reasons, and this level of error does not necessary reoccur when the test is repeated. Therefore, we cannot be certain that the improvement in error scores was only caused by the presence of the dog. Moreover, performance in attention and concentration tests depends strongly on the participant's motivation (Büttner & Schmidt-Atzert, 2004) and, given our study design, it is impossible to distinguish motivational effects from other mechanisms like physiological effects. This may not be the disadvantage it first appears, however, since we can conclude that the different conditions influence the children's motivation in different ways. Given the stated theory, the dog seems to have improved the children's motivation. But the effect of interacting with the dog before completing the tasks, and the effect of the mere presence of the dog while children completed the tasks cannot be separated because we did not address each question separately.

Finally, relatively few controlled studies use PIR HEG. Its application is based on the hypothesis that changes in thermal emission reflect changes in neuronal activity. No studies confirm these underlying neuronal mechanisms, although some early clinical studies show PIR HEG can be used to successfully treat patients (Carmen, 2004; Mize, 2004; Stokes & Lappin, 2010; Toomin & Carmen, 1999). Moreover, there are preliminary results from studies with near infrared hemoencephalography, a related method (Coben & Padolsky, 2008; Mihara et al., 2013; Serra-Sala, Tomoneda-Gallart, & Pérez-Àlvarez, 2012). Our PIR HEG results are very promising, but should be interpreted with caution.

Strengths

We tested a non-clinical sample in this study. The results are therefore relevant for a majority of school-aged children and "school dog" projects in classes with normally developing children. We see this as a clear strength of this study. We excluded children who owned a dog at home to control for the fact that some children have constant contact with dogs and others don't. However, it remains unclear if a dog at home leads to an enhanced effect, or if the presence of a dog e.g. at school or in a therapeutic setting may therefore have an effect ceiling. We found that it is not necessary to have a previous or existing relationship with the dog, although familiar dogs may have a stronger effect, at least with respect to stress-buffering (Baun, Bergstrom, Langston, & Thoma, 1984).

We systematically controlled for many factors, such as daytime effects and room temperature. The high comparability of the two conditions we tested is a further strength. AIBO was a most comparable interaction partner to a live dog, and allowed us to distinguish between the effect of a living animal with warm fur and free will and the effect of a simulacrum.

Our study was also strengthened by the combination of different techniques of measurement. It is unique in combining an established method of measuring attention during performance of neuropsychological tasks, with a new approach that simultaneously measures a neurobiological correlate of attention processes. This multimodal approach allows us to speculate on possible mechanisms, and allows us to raise questions that can be addressed in future research.

Further directions

Future studies should systematically evaluate the effects of the presence of a dog on populations of different ages and genders, as well as populations with different psychological and medical limitations. In particular we suggest that research might lead to improvements for children with attention problems such as ADHD. Such research is pressing, given the growing number of animal-assisted therapy programs for children with attention deficits. We do not yet know if these children also benefit from interacting with animals, though we suspect that the benefits for this population might be even greater than for normal children, since there might be a ceiling effect for the population we investigated. So called "low-performers" may see higher performance gains than already "high-performers" (Finke et al., 2010).

Further studies should be designed to distinguish between the effect of the mere presence of a dog, and the effect of interacting with a dog. The impact of familiarity with a dog on children's attention and concentration should also be addressed in future studies, along with the effect of different breeds of dog. All these factors are relevant for school dog programs and dog-assisted therapies.

Conclusion

Although our results are preliminary, they imply that interacting with animals and being in their presence, and, in particular, the presence of dogs can enhance human attention and concentration in some tasks. Nor does the presence of a dog seem to distract children. Given our results, we suggest investigating different conditions and different forms of attention processes that may influence this effect. Our study supports the claim that interacting with a dog and being in the presence of a dog can increase the attention and concentration performance of children.

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