



Pet dogs succeed where human companions fail: The presence of pet dogs reduces pain

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ARTICLE INFO

Keywords:

Social support
Pet dogs
Subjective pain ratings
Pain tolerance
Physiological reactivity
EDA
ECG
Facial EMG
Cold-pressor task

ABSTRACT

Social support from family and friends, albeit associated with beneficial health effects, does not always help to cope with pain. This may be because humans elicit mixed expectations of social support and evaluative judgment. The present studies aimed to test whether pet dogs are a more beneficial source of support in a painful situation than human companions because they are *not* evaluative. For this, 74 (Study 1) and 50 (Study 2) women completed a cold-pressor task in the presence of either their own (S1) or an unfamiliar (S2) dog, a friend (S1), or an unknown human companion (S2), or alone. In both studies, participants reported less pain and exhibited less pain behavior in the presence of dogs compared to human companions. Reactions to pain were moderated by attitudes towards dogs in S2. This suggests that pet dogs may help individuals to cope with painful situations, especially if the individual in pain generally feels affectionate towards dogs.

1. Introduction

Pain is a common feature of everyday life that impacts strongly on well-being. Individuals with persistent pain often report a loss of interest in daily activities and a decline in the quality of their social relationships (Bannon et al., 2021). The experience of pain is influenced by various psychological factors, including cognitive, emotional, and social aspects (Cano & Williams, 2010; Guo et al., 2020; Peters, 2015), which together shape an individual's perception and response to pain stimuli. Hence, understanding the significance of these psychological factors is crucial for improving pain management and overall patient well-being. Among these factors, *social support* emerges as a promising candidate that plays a vital role in how individuals cope with painful experiences.

According to the buffering hypothesis, perceived social support serves as a buffer in stressful situations (Cohen & McKay, 1984). Correspondingly, social support has been associated with positive effects on individuals' general health (Helgeson, 2003; Uchino, 2006; Uchino et al., 1996). Yet, research on the effect of social support on pain reveals inconsistent results. Whereas some studies find that the presence of a friend or partner can reduce pain intensity ratings and psychological

distress, both acutely (Brown et al., 2003; López-Martínez et al., 2008; Master et al., 2009; Roberts et al., 2015) and prospectively (e.g., over a period of three years (Evers et al., 2003; Lucas & Chopik, 2020; Sharma et al., 2003)), other research indicates that the presence of a partner or a friend may increase both chronic (Bernardes et al., 2017; Block et al., 1980; Schwartz et al., 2005; Solé et al., 2020) and acute pain (Che et al., 2018; Jackson et al., 2005; McClelland & McCubbin, 2008; Sullivan et al., 2004; Tracy, 2017).

Krahé and colleagues (Krahé et al., 2013; Krahé & Fotopoulou, 2018) disentangle these contradictory findings and conclude that social support only decreases pain perception when it functions as a predictive signal of safety. Yet, when supporting entities are perceived as potential threats, their presence may have opposite effects. Specifically, social-evaluative threat results when individuals feel evaluated by others (Dickerson & Kemeny, 2004). Thus, a potentially evaluative other increases rather than decreases stress responses during an acute psychological stressor (Dickerson & Kemeny, 2004; Kors et al., 1997; McClelland & McCubbin, 2008). Further, to comply with social demands, individuals under social-evaluative threat experience a need to elicit empathy for their pain and for the difficulty of bearing up with the

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task, stimulating increased communication of pain and higher pain ratings (Cano, 2004; Sullivan et al., 2001, 2004). This gives rise to the idea that a *naturally non-evaluative* entity such as a pet dog, which by its very nature does not socially judge the pet owner, might be a more efficient source of support in a painful situation than the presence of a human companion. The present studies aimed to address this issue.

1.1. The presence of dogs in painful situations

Pet dogs are commonly seen as family members and friends. As such, individuals often feel just as close to their pets as to their relatives and friends. Overall, pet ownership has many benefits with regards to both mental and physical health (McConnell et al., 2011, 2017). This may be because pets generally provide unconditional love and nonjudgmental support independent of social or cultural norms, or the personal attributes of their counterparts (Pachana et al., 2011; Walsh, 2009), which may make them a more reliable source of social support than potentially evaluating humans (McNicholas et al., 2005). Specifically, the presence of a dog seems to be more efficient in reducing physiological stress reactions (heart rate and cortisol level increase to a psychological stressor) than the presence of a friend (Polheber & Matchock, 2014). Similarly, Allen and colleagues (Allen et al., 1991; Allen et al., 2002) found that the presence of a person's own pet dog (or cat) reduced psychological stress during a mental arithmetic test and a cold-pressor (i.e., a painful) task compared to the presence of a friend and spouse. The authors explicitly note that they conceptualized the pet condition to investigate the social support of “naturally occurring nonevaluative others” (Allen et al., 2002, p. 737). That is, they expected participants' pets to create a naturally supportive environment, where the animals' presence is comforting without the evaluative pressures that human companions might impose.

We wanted to extend these findings by explicitly measuring pain reports and behaviors during a painful experimental task (Studies 1 and 2, see below). Specifically, unlike previous studies that predominantly focused on the effect of dogs on *stress* outcomes, we specifically targeted pain perceptions and behaviors using a multivariate approach including subjective pain ratings, physiological responses, and behavioral observations (Study 1, see below). Additionally, we extended the scope of the research by assessing whether the social support effect of dogs extends to an unfamiliar pet dog that accompanies the individual in pain (Study 2, see below). This is important because it opens the door to providing the benefits of animal-assisted interventions to people who do not own a pet or cannot be accompanied by their own pet. We further compared the social support effect provided by dogs with the effect of friends (Study 1) and unfamiliar humans (Study 2).

2. Study 1

In Study 1, we assessed whether dogs are better supporters than humans during a painful task by measuring the pain individuals reported and exhibited during a cold-pressor task (Mitchell et al., 2004; Wolf & Hardy, 1941) in the presence of their own pet dog, in the presence of a same-sex friend, or alone. As pain-related behaviors differ between women and men (Unruh, 1996) and women react differently to social support during acute pain than men (McClelland & McCubbin, 2008), we only included women in our sample, similar to other studies in this domain (Allen et al., 1991).

All participants were pet owners in order to control for the protective effects associated with pet ownership in general (Allen et al., 2002; El-Alayli et al., 2006; McConnell et al., 2011). Further, we used a multivariate pain assessment including: (a) subjective-verbal (i.e., pain reports), (b) motoric-behavioral (i.e., pain-related facial expressions and pain tolerance), (c) physiological stress measures (i.e., skin conductance), and (d) pain-coping measures (i.e., helplessness). This multivariate approach represents a decided advantage over previous studies on the pain-relieving effects of humans and animals (see above). In

Study 1, we compared the effects of the presence of a person's own pet dog to the effects of the presence of a close friend who provided *passive* social support (i.e., the companion's presence was not explicitly framed as support and we did not explicitly encourage (but also did not prohibit) supportive gestures).

Our primary aim was to compare the effects of dog companionship with friend companionship during a pain event compared to a control condition where participants experienced pain alone. We predicted that in the presence of their dog pet owners would report lower pain intensity and better pain coping abilities, show less intense facial displays of pain, reduced physiological pain responses, and greater pain tolerance than pet owners in the absence of any supporting entity. We expected smaller social support effects on pain reports and pain behaviors for pet owners in the presence of their friend compared to pet owners in the absence of any supporting entity. That is, we hypothesized that the difference in pain experience and pain reports between participants enduring pain alone and those in the company of dogs would be *significant* and *larger* compared to the difference between participants enduring pain alone and those in the company of friends, with the latter difference potentially being *non-significant*. We chose the “alone” condition as a baseline because this is a more conservative approach to investigate whether dogs are more effective supporters than friends in painful situations. This comparison allows for a clearer assessment of the relative impact of canine companionship compared to human companionship on pain perception and behaviors.

2.1. Materials and methods

2.1.1. Participants

A power analysis aiming for 80 % power at $\alpha = 0.05$ conducted with the R package *SSDbain* (Fu et al., 2022) based on findings from previous studies (Allen et al., 1991; Allen et al., 2002) that found large effect sizes of pet/dog support on stress measures indicated that a sample size between 17 and 23 participants per group would be adequate to detect the expected effects. Hence, to account for missing data due to technical problems or artifact in physiological measures, we recruited a total of 74 female pet owners (mean age 27.9 years; range 18–55 years) as participants for this study. All participants either currently owned or had owned a dog or a cat in the last five years.¹ All reported being in good health and none took prescription medication. Chronic pain patients were excluded from participation. Participants were mainly recruited via flyers at veterinarians and at shops that sell pet food and via online advertisements posted on Facebook or published in newsletters. The data collection took place from August 05 to September 18, 2013, at our psychophysiological laboratory at Humboldt-University.

The study was carried out in accordance with the guidelines of the Declaration of Helsinki (except for preregistration) and approved by the Institutional Ethics Committee (Application 2013-04 approved on 03-19-2013). Participants were informed that they had the right to terminate participation at any time and that their responses were confidential. Participants received €10 for their participation. In the dog condition, they received an additional €5 expense allowance for bringing their dog, and in the friend condition, friends also received €10 for their participation.

2.1.2. Pain induction

We used the cold-pressor task to induce pain through the immersion of a participant's hand in cold water. For this, a container is filled with

¹ As it is well established that pet ownership—including cat ownership—can buffer stress (Allen et al., 2002; El-Alayli et al., 2006; McConnell et al., 2011), we felt that it was important that all participants were pet owners. As it was difficult to recruit dog owners, we allowed cat owners to also participate in the non-dog conditions. Approximately 75 % of the participants were dog owners.

cold water and participants are instructed to immerse one hand into the cold water, keeping it in the water for as long as they can tolerate (see below for a detailed description of our specific procedure). The cold-pressor task produces a reproducible and controlled pain stimulus, making it a standard tool for studying pain perception, pain tolerance, and the effectiveness of analgesic interventions.

2.1.3. Pain-related measures

2.1.3.1. Subjective-verbal level of pain. Participants were prompted to report pain intensity twice: After 30 s of immersion and immediately after they withdrew their hands from the cold water. For this, they used a visual analog scale ranging from 0 (= *no pain*) to 100 (= *worst pain imaginable*) (Jensen & Karoly, 2010). Due to a technical error, data from six participants was missing for one or both of these time points.

2.1.3.2. Physiological level of pain. Spontaneous fluctuations in skin conductance (NS SCRs) correlate with stress and pain reports (Katkin, 1965; Ledowski et al., 2006, 2007). Hence, skin conductance was assessed using a BioNex Galvanic Skin Conductance amplifier with Mindware 8 mm Ag/AgCl electrodes filled with a 0.05 molar NaCl electrolyte solution. Due to equipment malfunction, the data for five participants were missing. Physiological pain reactions were operationalized as the number of skin conductance fluctuations exceeding 0.05 μ S during the immersion time period (Dawson et al., 1990). NS SCR frequency was calculated by dividing the NS SCRs by the total immersion duration in minutes. Respiration was recorded using a Mindware Respiratory chest belt to control for respiration-induced artifacts in skin conductance. NS SCRs due to respiratory artifacts were excluded from the analysis. NS SCR data of ten participants (four of them in the alone condition, two in the friend condition, and four in the dog condition) were removed from the analyses due to excessive artifacts.

2.1.3.3. Motoric-behavioral level of pain. Pain tolerance was operationalized as the total time participants held their hands in the water (rounded to the nearest second). Self-reported pain has been found to correlate with the intensity of facial muscle activity such as jaw clenching and frowning (Feldt, 2000; Rakel & Herr, 2004; Willis et al., 2003). Hence, we assessed the muscular activity of the *Masseter* (jaw clenching) and *Corrugator Supercilii* (frowning) on the left side of the face with facial electromyography (facial EMG). We used bipolar placements of 4 mm Ag/AgCl surface electrodes by Biopac Systems with SignaGel electrode gel by Parker Laboratories. Electrode placement was in accordance with the guidelines for electromyographic research (Fridlund & Cacioppo, 1986). All pairs of electrodes were referenced to a forehead electrode placed near the midline. The skin was cleansed with Lemon Prep SkinPrep and rubbing alcohol. A Mindware BioNex system with a 30–300 Hz band pass filter and a 50 Hz notch filter was used to amplify the raw EMG signal. The amplified raw EMG signal was sampled at 1000 Hz and stored on disk. The data were rectified offline, smoothed, and visually inspected for artifacts (e.g., sneezing, coughing, gross body movements). Facial EMG data of eleven participants (five of them in the alone condition, five in the friend condition, and one in the dog condition) were removed from the analysis due to excessive artifacts. Facial display of pain was operationalized as the mean facial EMG during the last 10 s beforehand withdrawal. The last 90 s of the baseline video were used as facial EMG baseline.

2.1.3.4. Pain-coping measures. Self-reported pain-coping style was operationalized as helplessness and measured immediately following the cold-pressor task with a subscale of the Pain Catastrophizing Scale (Sullivan et al., 1995), comprising six items (e.g., “There is nothing I could do to reduce the intensity of the pain”) and slightly modified instructions to capture state helplessness (see S3).

2.1.4. Control measures

2.1.4.1. Bonding with the social partner. To ensure a close relationship between the pain sufferer and her social partner (i.e., friend vs. dog), the closeness of the relationship was assessed using the ‘Inclusion of Other and the Self Scale’ (IOS; Aron et al., 1992) at the end of the experiment. In addition, all participants (i.e., pet owners) were asked to indicate their feelings towards pets in general, the number of pets at home, and the length of their pet ownership, allowing to control for benefits stemming from pet ownership in general.

2.1.4.2. Activity of social partners and contact with participants. To ensure that friends and dogs were comparable in terms of their bodily activity, supporting communicative gestures during the painful task, and their excitement during the experimental session, two raters, both blind to the hypotheses tested, evaluated the videos of the friends and of the dogs taken during the individual test sessions. Specifically, they rated the dogs' and friends' bodily activity, their communicative gestures, and their excitement/stress on a scale ranging from 0 (= *the support giver did not move/did not show any gestures (and did not bark or speak)/was completely relaxed*) to 4 (= *the support giver was moving a lot/gesturing, barking or speaking a lot/very nervous and anxious*). Additionally, the raters measured how long dogs and friends looked towards the participant during the cold-pressor task, and conversely how long the participant looked at her dog or friend.

2.1.5. Procedure

Participants either came to the laboratory with a same-sex friend ($n = 25$), their pet dog ($n = 24$), or alone ($n = 25$). Assignment to these conditions was pseudo-random due to practical considerations. Specifically, not all participants had their pet dog available in Berlin city, as some dogs were kept at their parents' homes in rural areas (approximately 25 %). Thus, the assignment was based on both the randomization protocol and the feasibility of bringing their dog to the lab.

Upon arrival, participants received and signed a written informed consent form. They were then seated in a comfortable chair and electrodes were attached and the experimenter left the room. After watching a relaxing baseline video showing water lapping at a beach in the sunset, participants immersed their dominant hand into 2 to 3 degrees Celsius water and were encouraged to leave it for as long as possible. After a maximum of 5 min of immersion, participants were requested via loudspeakers to withdraw their hands.

During the whole experimental procedure, the ‘support giver’ (dog or friend) sat quietly on a blanket (dog) or chair (friend) diagonally opposite to the right of participants in a corner of the laboratory about four meters away watching but not interacting with the participant (even though it was not explicitly encouraged, we did not prohibit eye contact between friends and participants or supportive smiles of friends). Almost all dogs followed the instructions, with the help of their owners, of lying down on the blanket and remaining quiet throughout the cold-pressor task; about half of the dogs were put on a leash during the experimental procedure (participants decided themselves whether they thought this was necessary). We monitored support givers via video camera. In the alone condition, participants were alone in the laboratory. Following the cold-pressor task, participants completed the questionnaires. They were then thanked, fully debriefed, and paid.

2.1.6. Statistical analyses

As we aimed to test whether dogs have an effect on the pain measures, whereas friends have a lesser or no effect, we decided to use a Bayesian approach (Ortega & Navarrete, 2017). In Bayesian hypothesis testing, the Bayes Factor (BF) indicates whether the data is more likely given the alternative hypothesis (H1; that there is a difference between conditions) or the null hypothesis (H0; that there is no difference between conditions). If the BF is >1 , the data support the H1 more strongly

than the H0, whereas if the BF is <1, the data support the H0 more strongly than the H1 (Kass & Raftery, 1995).

Hence, in contrast to the NHST, with the Bayesian approach, we were able to test not only if there is an effect (a difference between the dog and alone condition), but also if there is no effect (no difference between the friend and alone condition). For this, we compared the full model (friend ≠ alone ≠ dog) against two models with one equality constraint each (F = A: friend = alone ≠ dog; D = A: friend ≠ alone = dog). That is, in the former case, if the constraint model (F = A) is preferred (BF < 1), outcome measures do not differ between the friend and the alone condition. In contrast, if the full model is preferred (BF > 1), outcome measures differ between the friend and the alone condition. Similarly, in the latter case, if the constraint model (D = A) is preferred (BF < 1), outcome measures do not differ between the dog and the alone condition. In contrast, if the full model is preferred (BF > 1), outcome measures differ between the dog and the alone condition. Yet, note that a BF <1 but >1/3 only constitutes weak evidence for the absence of an effect. Similarly, a BF >1 but <3 only constitutes weak evidence for the presence of an effect (Kass & Raftery, 1995). Hence, we considered it strong evidence for or against an effect of dogs and friends if the BF was <1/3 or >3.

Further, we compared the difference between the dog and alone condition with the difference between the friend and alone condition to test whether or not dogs are better support givers than friends by dividing the first constraint model by the second constraint model (F = A/D = A) (Ekong et al., 2021; Morey, 2015). If the resulting BF is >3, we can conclude that dogs are better support givers than friends with strong evidence (see above). All analyses were performed using R. Specifically, we used the BayesFactor R package (Morey & Rouder, 2014) to conduct the Bayesian one-way analyses of variance (ANOVAs).

For the analyses including the control measures, we only report the three additional comparisons to the comparison of the full model against the null model, if the BF of this first model comparison was >1. As the ratings of the second part of the control analyses only refer to two conditions (dog and friend), we conducted Bayesian *t*-tests.

Data from two participants were excluded because they did not report a close relationship with their friend or their dog, respectively; one participant had to be additionally excluded because the water temperature during the cold-pressor task exceeded 6 degrees Celsius. Prior to analyses, outliers were identified by visual inspection of the cluster of points within a boxplot and removed accordingly. We provide all datasets and a Markdown HTML with all analyses, both with the full dataset and with the outliers removed, at OSF: <https://osf.io/ykte3/>.

2.2. Results

The three experimental groups in our between-subjects design did not substantially differ regarding the number of pets at home, length of pet ownership, and emotional closeness to their pets. Furthermore, dogs and friends did not differ substantially in their bodily activity or their excitement or stress behaviors during the painful task. However, we found weak evidence that they differed in their communicative gestures and in the frequency with which they looked at the participant. Friends communicated more with participants or looked at participants more often than dogs did. Participants, by contrast, looked about equally long at their dogs and their friends. Further, participants did not feel substantially closer to their dogs than to their friends (see S1 Table).

2.2.1. Pain-related measures

Across all domains the same pattern was found: Participants reported and showed less pain and they felt less helpless in the dog condition compared to the alone condition. The only exception here was Corrugator activity, where the BF was lower than 3, which indicates only weak evidence in favor of a difference between the dog and alone condition (see Table 1, for the subjective-verbal and physiological level of pain and Table 2, for the motoric-behavioral level of pain and helplessness

Table 1
Study 1 Subjective-verbal and physiological level of pain.

Model	1: Full model/null model	2: Full model/F = A model	3: Full model/D = A model	4: F = A model/D = A model
Bayes factor				
After 30 s ^a	6.60 ± 0.02	0.33 ± 0.02	12.93 ± 0.02	38.97 ± 0.03
	%	%	%	%
After immersion ^b	0.67 ± 0.02	0.43 ± 0.02	2.26 ± 0.02	5.28 ± 0.03
	%	%	%	%
NS SCR	32.24 ±	0.31 ± 0.01	13.47 ± 0.01	43.57 ± 0.01
frequency ^c	0.01 %	%	%	%

Full model: friend ≠ alone ≠ dog. F = A model: friend = alone ≠ dog. D = A model: friend ≠ alone = dog.

^a N = 65.

^b N = 70.

^c N = 56.

Table 2
Study 1 Motoric-behavioral level of pain and helplessness (pain-coping measure).

Model	1: Full model/null model	2: Full model/F = A model	3: Full model/D = A model	4: F = A model/D = A model
Bayes factor				
Pain tolerance ^a	1.39 ±	0.35 ± 0.03	3.22 ± 0.03	9.17 ± 0.04
	0.03 %	%	%	%
Corrugator activity ^b	0.43 ±	0.97 ± 0.03	1.30 ± 0.03	1.33 ± 0.04
	0.02 %	%	%	%
Masseter activity ^c	1.12 ±	0.54 ± 0.01	3.67 ± 0.02	6.81 ± 0.03
	0.01 %	%	%	%
Helplessness ^d	1.62 ±	0.34 ± 0.01	3.02 ± 0.01	8.81 ± 0.02
	0.01 %	%	%	%

Full model: friend ≠ alone ≠ dog. F = A model: friend = alone ≠ dog. D = A model: friend ≠ alone = dog.

^a N = 71.

^b N = 59.

^c N = 58.

^d N = 71.

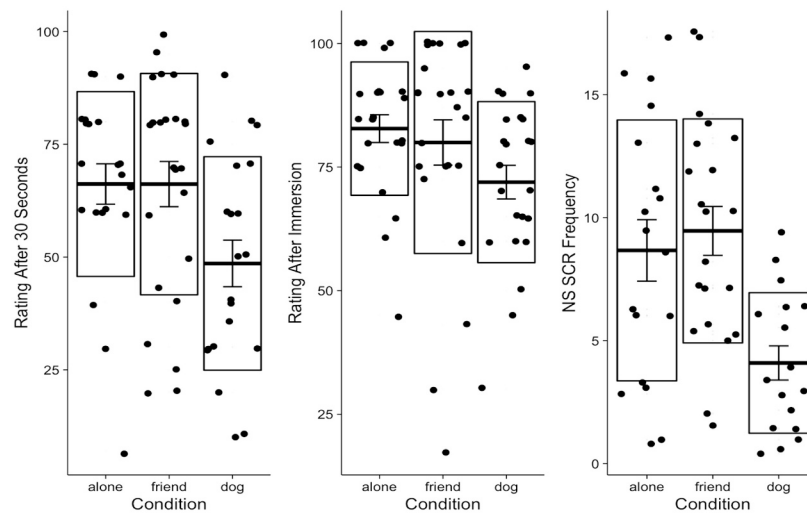
(pain-coping abilities), column 3). Importantly, no substantial differences emerged when comparing the friend with the alone condition (Tables 1 and 2, column 2). Hence, as the differences between the dog and alone condition were larger than the differences between the friend and alone condition (with the only exception of Corrugator activity), overall dog support was more efficient than friend support in reducing cold-pressor pain (Tables 1 and 2, column 4; Fig. 1).

2.3. Discussion

Based on the safety value of non-evaluative social others during painful situations (Che et al., 2018; Kors et al., 1997; Krahé et al., 2013), we predicted that the presence of a dog who offers unconditional, non-evaluative support would reduce pain more strongly than the presence of a potentially evaluative human social partner. Specifically, we predicted that—compared to the absence of any social support—the presence of a pet dog is more effective than the presence of a close friend in reducing pain reports and pain behaviors and improving overall coping abilities during a cold-pressor task. In line with this prediction, participants accompanied by their dog reported less pain and showed lower physiological pain reactions, greater pain tolerance, and less intense facial displays of pain as well as felt less helpless than participants without social support and also as participants accompanied by their friends.

In contrast to the presence of pet dogs, the mere presence of close friends may have triggered social demands and social-evaluative threat in the painful situation (Dickerson & Kemeny, 2004). In fact, the

[a] Subjective-verbal and physiological level of pain



[b] Motoric-behavioral level of pain and helplessness

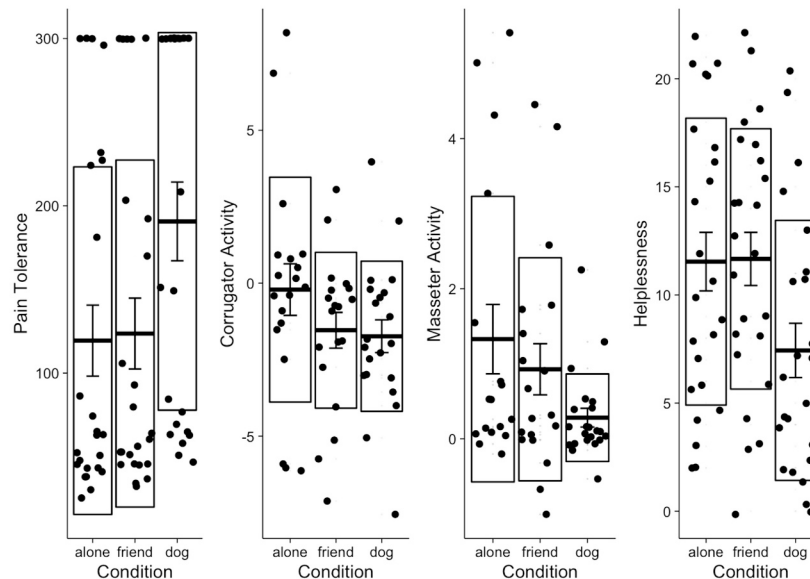


Fig. 1. Means, standard errors and distribution of the pain indices as a function of condition (S1).

[a] Subjective-verbal and physiological pain indices as a function of the support condition (dog vs. friend vs. alone) in Study 1.

[b] Motoric-behavioral pain indices and feelings of helplessness (pain-coping measure) as a function of the support condition (dog vs. friend vs. alone) in Study 1.

increased eye contact frequency between participants and friends compared to participants and dogs may be a reason for the heightened threat perceptions in the friend compared to the dog condition. This is in line with the finding that stressed women, even though they appreciated the comforting efforts of their family and friends, preferred being alone with their dog when suffering pain, because in the dog's company, no social pretenses were necessary and no social expectations needed to be satisfied (Allen, 1995). In the present study, the social demand implied by the presence of a friend may have counteracted the otherwise soothing effect of a friend's social support (Allen et al., 1991; Kors et al., 1997; McClelland & McCubbin, 2008). In turn, dog but not friend support may have helped individuals to calm down and lower their stress level, and to cope with the painful stimulus (Che et al., 2018). As a result, the friend and the alone condition did not differ from each other.

As all of our participants were pet owners, our results cannot merely be explained by increased psychological resources associated with pet

ownership in general (Allen et al., 2002; El-Alayli et al., 2006; McConnell et al., 2011). Likewise, differences in active support behavior like eye contact frequency between dogs and friends cannot explain the soothing effect of the dogs' presence either, as results showed that friends looked more often towards the participants than did dogs.

In sum, participants exhibited the least stress responses when accompanied by their dogs in a painful situation (Allen et al., 2002). Hence, we could replicate and extend prior findings by examining other relevant pain-related constructs. Participants further coped most efficiently with the painful stimulus and reported to feel the least pain and showed the least pain-related behaviors in the presence of their beloved pet dogs compared to the other conditions.

In Study 1, consistent with previous research on the stress-buffering effects of dogs, participants were exposed to a painful stimulus while accompanied by their own dogs. This setup inherently involves dogs that participants have a close, familiar bond with, often considered "close

friends” (McConnell et al., 2017). This relationship could influence the perceived pain-relieving effects of the dogs, raising the question of whether these effects are due to the dogs' presence or their status as close but non-evaluative friends (see below). To explore this notion further, Study 2 examined whether the presence of unfamiliar dogs also provides pain relief.

3. Study 2

In Study 1, participants experienced pain while being in the presence of their own dogs to whom they felt close and whom they loved. According to the intimacy model of pain (Cano & Williams, 2010), people in pain primarily seek love and comfort. As noted above, pet dogs are excellent providers of social support because, in contrast to humans, their mere presence signals unconditional comfort, relief, and nonjudgmental devotion (Walsh, 2009). Study 1 suggests that this provides pet owners with a positive emotional buffer that served as a safety signal in a threatening situation (Krahé et al., 2013) and hence decreased subjectively felt pain (Loggia et al., 2008; Silvestrini et al., 2011; Sobo et al., 2006; Weisenberg et al., 1998), alleviated threat expectancy and increased pain tolerance (Al Absi & Rokke, 1991; Dehghani et al., 2018; Todd et al., 2015). However, the question arises whether the social support effect of dogs is solely due to the non-evaluative presence of the dog or also depends on the loving bond between the pet owner and the dog.

The aim of Study 2 was to test whether the bond between dog owners and their dogs is essential for the social support effects observed in Study 1. For this, we assessed whether the dog support effects observed in Study 1 could be replicated by introducing an unfamiliar dog during a painful situation. Similar to a study by Fontana et al. (1999), it may not make a difference whether the non-evaluative other (i.e., the dog) is known or unknown. That is, individuals may also benefit from an unfamiliar (non-evaluative) dog as compared to an unfamiliar (evaluative) human partner. If, however, a close relationship to the dog is crucial for the “dog effect”, the overall pain-buffering effect of dogs should be reduced in Study 2 and only people who have a strong positive attitude towards dogs—who adore dogs in general—should feel less pain in the presence of unknown dogs. Conversely, people who are less attached to dogs, in general, should not experience them as supportive.

To make the two support conditions as similar as possible, we also adapted the closeness of the relationship to the human supporter: Participants experienced pain either in the presence of unfamiliar dogs, unfamiliar humans, or alone. In addition, we aimed to reduce the ambiguous intentions and unclear function of support givers during the painful task in Study 2. Specifically, in Study 1 friends were not explicitly encouraged to show active signs of support and only watched the participants during the painful task. We chose this kind of support as it is the common procedure also used in prior studies (McClelland & McCubbin, 2008). However, preventing friends from expressing social support with reassuring words or friendly gestures may have reinforced the evaluative aspect of their presence. According to Krahé and colleagues (Krahé et al., 2013) passive support or the mere presence of others during painful situations may neither amplify nor weaken the threat value of painful situations (in line with these thoughts some studies did not find an effect of the (passive) presence of unknown dogs on pain perceptions (Wagner et al., 2021)). In contrast, active support can signal safety and thus reduce pain (Mohr et al., 2018). As hand-touching is a well-established signal of comfort (Coan et al., 2006; Fotopoulou et al., 2022; Henricson et al., 2008; Krahé et al., 2016), in Study 2, human support givers allowed participants to touch their hands whereas dog support givers allowed participants to touch their heads during the painful task. Thus, in contrast to Study 1, participants completed the cold-pressor task in the presence of *unfamiliar* but *actively* supporting social others (humans and dogs). To keep the conditions ‘unfamiliar person’ and ‘unfamiliar dog’ as comparable as possible, we introduced the two as nursing staff familiar with the needs of pain

patients.

In Study 2, we drew our sample from the general population (i.e., we only recorded pet ownership but did not exclusively select participants depending on their momentary or prior dog or cat ownership) to increase generalizability; therefore, we adjusted our study design: In Study 2, we used a within-subjects design to control for individual differences (e.g., health benefits due to pet ownership).

In line with our findings from Study 1, we assumed that participants experiencing the cold-pressor task with active support from unfamiliar dogs would cope better with the pain and report lower pain intensity, exhibit reduced facial displays of pain as well as physiological pain responses, and demonstrate greater pain tolerance compared to when the support was provided by a human companion. Further, we explored the possibility that the condition effects are moderated by participants' attitudes towards dogs. In fact, it is very plausible that the positive effect of the dogs' presence may be less pronounced for people with a less positive attitude towards dogs. Hence in Study 2, we allowed participants to touch the unfamiliar dogs actively and also investigated the moderating effects of affinity for dogs, addressing the gaps highlighted by Wagner et al. (2021).

3.1. Materials and methods

3.1.1. Participants

Based on the results of Study 1, we used a more conservative effect size of Cohen's $f = 0.25$ for our power analysis in Study 2. Thus, aiming for 90 % power at $\alpha = 0.05$, 36 participants would be required for the current design. As there are currently no satisfactory a priori power analysis tools for Bayesian repeated-measures ANOVAs, we used a power analysis for a “regular” frequentist repeated-measures ANOVA that can be considered a lower bound for a power analysis for a Bayesian ANOVA.

To compensate for missing data due to technical problems or artifact in physiological measures, a total of 50 healthy women (mean age 26.6 years; range 19–55 years) participated. General inclusion criteria were the same as those used in Study 1, except that participants were not required to be dog or cat owners. Participants were screened with regard to fear of dogs and only participants who reported that they feel quite comfortable in the presence of dogs were included. The data collection took place from October 23rd to December 13th 2013, at our psychophysiological laboratory at Humboldt-University.

The study was carried out in accordance with the guidelines of the Declaration of Helsinki (except for preregistration) and approved by the Institutional Ethics Committee (Application 2013-37 approved on 10-09-2013). Participants were aware that they had the right to terminate participation at any time and that their responses were confidential. Participants received €15 for their participation in the approximately 90 min enduring experiment.

3.1.2. Pain-related measures

Measures of pain were identical to those used in Study 2, except that one additional *motoric-behavioral* pain measure (pain threshold), another *physiological* pain measure (heart rate), and an additional *pain-coping* measure (self-efficacy) were included in Study 2. EMG data of seven participants in all three conditions were removed from the analyses due to excessive artifacts.

To ensure consistency with Study 1, we also measured skin conductance. However, we will not report this data because it was measured on the hand with which participants touched support givers and thus was highly susceptible to artifacts.

3.1.2.1. Pain threshold. Pain threshold was defined as the time between hand immersion and the onset of pain (rounded to the nearest second). Data of two participants in all conditions and eight participants in one or two of the three conditions (one of them in the alone condition, three in

the person condition, and seven in the dog condition) were missing, as they forgot to indicate the time point of their first detection of pain.

3.1.2.2. Heart rate. During pain, heart rate increases (Tousignant-Lafamme et al., 2005). Hence, heart rate was continuously recorded at 1000 Hz using a Mindware BioNex acquisition unit. For this, the skin was first cleansed with rubbing alcohol; then, electrocardiography (ECG) recordings were obtained with two pre-jelled Mindware Ag/AgCl snap disposable vinyl electrodes placed on the participants' right collar bone and left lower rib and one pre-jelled Mindware Ag/AgCl snap disposable vinyl reference electrode placed on participants' right lower rib. A Mindware BioNex Impedance Cardiograph amplifier, using a bandpass filter of 0.5 Hz–100 Hz (and a 60 Hz notch filter), was used and the ECG signal was converted into R-wave intervals, which then were converted to beats per minute. Due to equipment malfunction, the data for three participants were missing. Artifacts and recording errors were corrected manually. Heart rate data of seven participants in one of the three conditions (two of them in the alone condition, two in the person condition, and three in the dog condition) were removed from the analyses due to excessive artifacts.

3.1.2.3. Self-efficacy. Participants also completed the self-efficacy scale (Jerusalem & Schwarzer, 1986), which had been slightly adapted to measure participants' momentary self-efficacy beliefs, on a 4-point Likert scale ranging from 1 (= *not at all*) to 4 (= *very much*).

3.1.3. Pain-unrelated self-report measures

In Study 2, we also included positive and negative affect to measure participants' overall well-being.

3.1.3.1. Affect. Immediately following each cold-pressor task, participants completed the Positive and Negative Affect Schedule (PANAS; Watson et al., 1988; German version by Krohne et al., 1996) with slightly adapted instructions to measure state affect on a 5-point Likert scale ranging from 1 (= *very slightly or not at all*) to 5 (= *extremely*) (Crawford & Henry, 2004).

3.1.4. Moderators

3.1.4.1. Attitude towards dogs. As negative and positive attitudes towards dogs might influence the stress-buffering effect of dogs (Somerville et al., 2008), participants rated their negative attitude ('concern about dogs') and their positive attitude towards dogs ('love for dogs') on a 100-point visual analog scale as part of a short online questionnaire, which they were asked to complete at least 24 h prior to the laboratory appointment. It is important to emphasize that none of our participants was frightened of touching or being close to dogs; still, some participants did not feel as attracted to dogs as others. In order to compare pain measures reported and shown by individuals with high versus low negative and positive attitudes towards dogs, a median split was performed on the two dimensions.

3.1.5. Additional measures

After the last cold-pressor task, participants additionally rated how evaluated they felt by dogs, human companions, and investigators and how close they felt towards these using the 'Inclusion of Other and the Self Scale' (IOS; Aron et al., 1992). Further, they rated the extent to which dogs, human companions, and investigators were perceived as empathic and the degree to which they felt supported by them.

3.1.6. Procedure

The procedure corresponded to the procedure in Study 1, except that all participants came alone to the laboratory and underwent all three conditions. All participants completed the cold-pressor task a) with an unknown dog, b) with an unknown person, and c) alone. The three

conditions were counterbalanced. Both support givers were introduced as caregivers who were there to reassure participants during the painful task.

Three different very calm and friendly dogs participated in this study. They all underwent thorough training prior to the first experimental session. The training was designed to ensure that the dogs behaved professionally and consistently across all experimental sessions. Specifically, dogs were trained to interact with participants in a supportive manner, ensuring that their behavior was consistent across different participants providing uniform social support. This included remaining calm and approachable and allowing strangers to touch them during the pain-inducing tasks. All three dogs were gradually acclimated to the laboratory setting to minimize any stress or anxiety that could affect their behavior. This involved familiarization with the equipment, sounds, and various aspects of the environment where the experiments took place. Dogs differed in size and age but resembled each other in friendliness and attentiveness to humans. During the cold-pressor task, they rested quietly in an armchair opposite to participants, looked at participants, and let participants touch their heads. Six different female confederates (blind to the aim of the study) assisted in this study as "unknown persons"; they were also trained prior to the first experimental session to appear professional and genuine to help participants feel at ease. During the cold-pressor task, confederates also sat in the armchair, looked at participants, and let them touch their hands.

To minimize discomfort related to touching strangers, we implemented several strategies: We clearly communicated the nature of the physical contact involved in the study and obtained explicit consent from participants. Detailed information about what to expect was provided, allowing participants to make informed decisions about their involvement. This included recruiting only participants who were not afraid of dogs (see above). Before any physical contact, participants were introduced to the support givers (whether human or animal) in a non-threatening and gradual manner. Allowing time for interaction and building familiarity also helped to reduce discomfort. We further ensured that support givers (humans or animals) were perceived as friendly, non-threatening and professional.

3.1.7. Statistical analyses

Congruent with Study 1, we used a Bayesian ANOVA to analyze whether human support differs from no support and dog support differs from no support and consequently whether dog support is better support than human support. In addition to the main analyses, we performed moderator analyses as well. For this, we compared the full model (condition: friend $\neq$ alone $\neq$ dog) with the interaction effect of condition with the moderators (negative and positive attitude towards dogs) against two models with one equality constraint each ($P = A$: person = alone $\neq$ dog; $D = A$: person $\neq$ alone = dog) with the interaction effect of $P = A$ or $D = A$ with the moderators. We further compared these comparisons with the comparisons of the full model without the interaction effect of condition with the moderators against the two constraint models without the interaction effect of $P = A$ or $D = A$ with the moderators. In case an interaction effect emerged, the Bayes factor for the full model with the interaction effect of condition with the respective moderator against the corresponding constraint model should be higher than the Bayes factor for the full model without the interaction effect of condition with the respective moderator against the corresponding constraint model. If this was the case, we further conducted separate analyses for individuals who have a less negative/positive and those who have a more negative/positive attitude towards dogs.

Data from two participants were excluded because, during the cold-pressor task, the dog did not behave appropriately (tried to walk away, turned their head away from participants, or barked/whined during the cold-pressor task); data from one participant were excluded because she reported boredom as reasons for hand withdrawal after the second cold-pressor trial. Finally, data from one participant were excluded because she refused to touch the hand of the unfamiliar person. Again, outliers

were identified prior to analyses by visual inspection of the cluster of points within a boxplot and removed accordingly.

3.2. Results

Similar to Study 1, as regards the motoric-behavioral indices of pain and the pain-coping and pain-unrelated self-report measures, participants showed less pain and felt less helpless in the dog condition compared to the alone condition (please note that Study 2 used a within-subjects design). They also felt more self-efficacious and reported more positive affect (see Table 3 for the motoric-behavioral level of pain and Table 4 for the pain-coping and affect measures, column 3). For the comparison between the person and the alone condition, no substantial differences emerged for pain threshold, positive affect, and self-efficacy beliefs; however, participants showed less pain and felt less helpless in the person condition (column 2). Yet, the differences between the dog and alone condition were larger than the differences between the person and alone condition (the only exception here was Masseter activity). Thus overall, dog support was more efficient than human support in reducing pain behaviors and increased pain coping abilities and positive affect (column 4; Fig. 2). These effects did not depend on the attitude towards dogs (see Table 5 for the motoric-behavioral level of pain).

By contrast, even though for pain reports and negative affect, similar main effects of dog versus human support were found (see Table 6 for the subjective-verbal level of pain and Table 4, for negative affect, column 4), these were fully qualified by the attitude towards dogs (see Tables 7a and 7b for the subjective-verbal level of pain and Tables 8a and 8b for the negative affect). Similarly, the unexpected main effect of reduced heart rate increases (from baseline) during human versus dog support (see Table 9, column 4) was also fully qualified by the attitude towards dogs (see Tables 10a and 10b for the physiological level of pain).

That is, participants who felt less negative and more positive towards dogs reported less pain after 30s in the dog compared to the person condition with no difference for individuals who felt less positive and more negative towards dogs (see Table 7b, column 4; Fig. 3). We obtained similar results for pain ratings after the hand was withdrawn, for heart rate increases, and for negative affect and when comparing participants who felt less negative towards dogs with participants who felt more negative towards dogs (see Tables 7b, 8b, 10b, column 4; Fig. 3). For heart rate increases and negative affect the pattern even reverses. That is, individuals who felt more negative towards dogs profited more from human support than from dog support in terms of showing lower heart rate increases and reporting lower negative affect in the person compared to the dog condition.

In sum, the results of Study 2 also suggest that overall dogs are better support givers than humans. However, for pain reports, negative affect,

Table 3
Study 2 Motoric-behavioral level of pain.

Model	1: Full model/null model	2: Full model/P = A model	3: Full model/D = A model	4: P = A model/D = A model
Bayes factor				
Pain threshold ^a	2.40 ± 0.65 %	0.38 ± 1.73 %	9.83 ± 1.43 %	25.95 ± 2.25 %
Pain tolerance ^b	277.79 ± 1.77 %	90.56 ± 1.88 %	399.92 ± 2.05 %	4.41 ± 2.78 %
Corrugator activity ^c	22.00 ± 0.54 %	14.67 ± 1.2 %	45.79 ± 1.35 %	3.12 ± 1.81 %
Masseter activity ^d	13.42 ± 1.12 %	20.87 ± 1.63 %	15.14 ± 3.94 %	0.73 ± 4.26 %

Full model: condition (person ≠ alone ≠ dog). P = A model: person = alone ≠ dog. D = A model: person ≠ alone = dog.

^a N = 44.
^b N = 46.
^c N = 39.
^d N = 39.

Table 4
Study 2 Pain-coping measures and affect.

Model	1: Full model/null model	2: Full model/P = A model	3: Full model/D = A model	4: P = A model/D = A model
Bayes factor				
Helplessness ^a	3707.16 ± 1.02 %	90.89 ± 1.74 %	10,247.77 ± 2.06 %	112.75 ± 2.7 %
Self-efficacy beliefs ^b	7.25 ± 3.65 %	0.61 ± 4.23 %	35.79 ± 3.93 %	58.88 ± 5.77 %
Positive affect ^c	94.42 ± 0.5 %	0.24 ± 0.88 %	65.02 ± 0.92 %	273.11 ± 1.27 %
Negative affect ^d	72.73 ± 1.69 %	3.78 ± 1.93 %	362.64 ± 1.89 %	95.91 ± 2.7 %

Full model: condition (person ≠ alone ≠ dog). P = A model: person = alone ≠ dog. D = A model: person ≠ alone = dog.

^a N = 46.
^b N = 46.
^c N = 46.
^d N = 46.

and physiological pain measures, this effect was moderated by people's attitudes towards dogs. That is, only participants who have a more positive or less negative attitude towards dogs profited from the dogs' presence during a painful situation on the subjective-verbal and physiological level of pain and with regards to reports of negative affect.

3.2.1. Additional measures

We further analyzed the effects of support condition on several additional (control) measures. Dogs were perceived as less evaluative than human companions; participants felt closer to dogs than to human companions and perceived dogs as more empathic and supportive than human companions (see S2 Table).

4. General discussion

In Study 1, we found that participants reported as well as showed less pain in the presence of their own dog compared to the presence of a human friend. These findings support the assumption that a non-evaluative supporting other such as a dog companion is more efficient in alleviating pain than a potentially evaluating supporting other. However, the dogs in Study 1 were participants' own dogs with whom they had a loving relationship. Further, friends were not explicitly given a supporting role thus leaving their role ambiguous, which likely made them appear more evaluative than supportive. Study 2 aimed to address these two issues by examining a) whether unfamiliar dogs would also have higher analgesic effects than unfamiliar humans and b) whether active support gestures may improve the effect of a human companions' presence.

Similar to Study 1, in Study 2, participants indicated less pain in the presence of an unfamiliar dog as compared to the alone condition on most measures. Thus, in line with studies that have investigated the effects of animal-assisted therapy on pain, the presence of an unfamiliar (actively supporting) dog reduces pain (Calcaterra et al., 2015). But are dogs also better support givers than actively supporting human companions?

In contrast to Study 1, Study 2 indicated that the presence of an actively supporting human companion was also efficient in reducing self-reported pain reports and behavioral pain expressions. This positive effect of humans in Study 2 was likely due to the clearer safety signal (or reduced threat signal) of the human companions in Study 2, who provided touch during the painful task (Fotopoulou et al., 2022; Krahé et al., 2016; Mohr et al., 2018). Additionally, the support giver was introduced as a health care professional who can be expected to properly understand the pain situation and to be well-intentioned. As such, the support givers' positive intentions towards the participant were made clear from the outset. The transparency of another's intentions is very

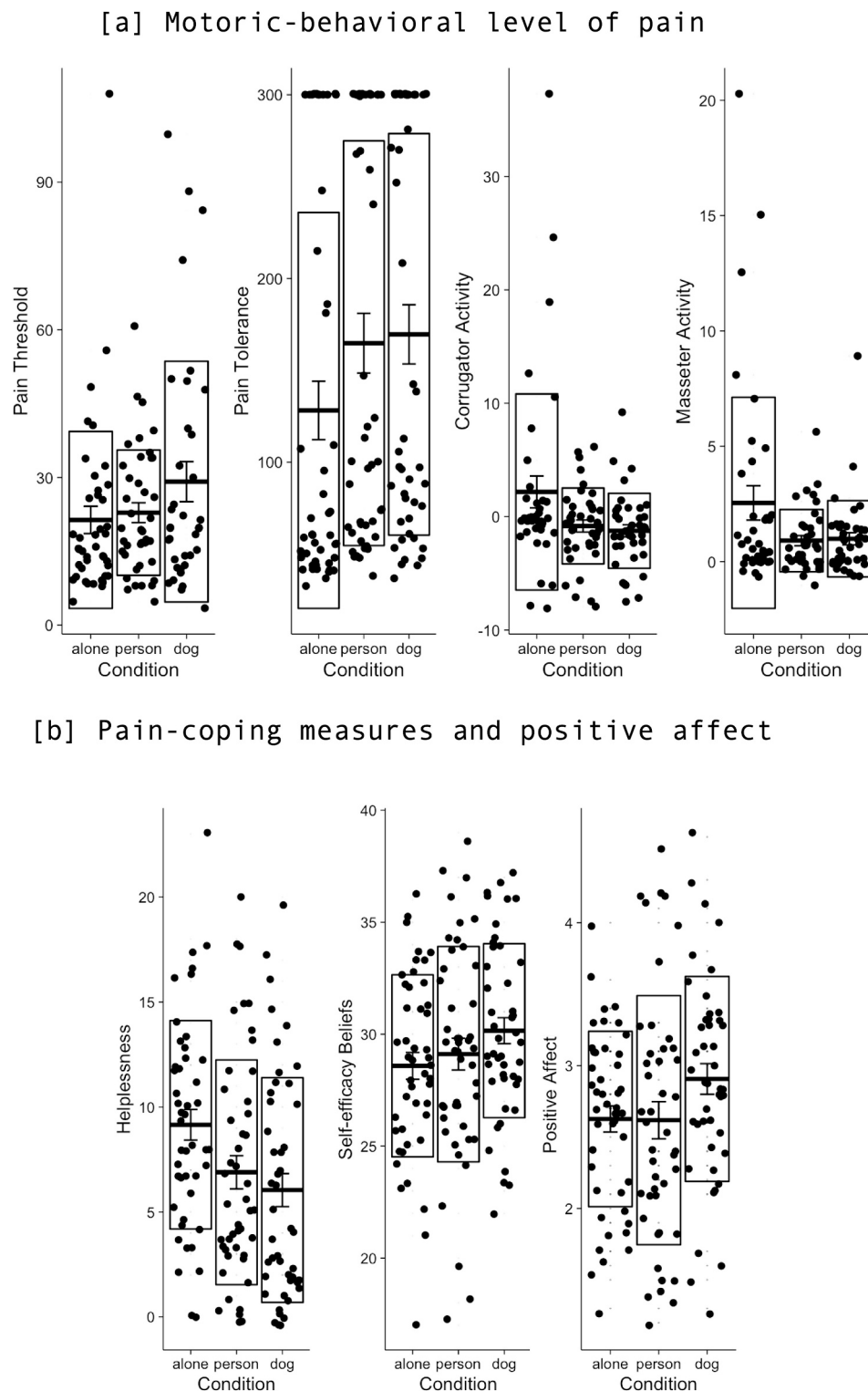


Fig. 2. Means, standard errors and distribution of the pain indices as a function of condition (S2).

[a] Motoric-behavioral pain indices as a function of the support condition (dog vs. person vs. alone) in Study 2.

[b] The pain-coping measures as well as positive affect as a function of the support condition (dog vs. person vs. alone) in Study 2.

important for the perceived safety value (Decety & Fotopoulou, 2015; Krahé et al., 2013).

However, except for the increased reduction of physiological stress (heart rate) and greater (yet still small) reduction of masseter activity during the person condition compared to the dog condition, the differences between the person and alone condition were smaller than the

differences between the dog and the alone condition. Further, participants did not report less pain after hand immersion, reduced pain onset, or improved positive affect or self-efficacy in the person condition compared to the alone condition. Additionally, despite their actively supporting gestures, participants perceived humans as much more evaluating than dogs. Thus, concerns about evaluation may still be a

Table 5
Study 2 Moderator analyses: Motoric-behavioral level of pain.

Model	1: Full model with IA/P = A model with IA	2: Full model without IA/P = A model without IA	3: Full model with IA/D = A model with IA	4: Full model without IA/D = A model without IA
Bayes factor				
Pain threshold				
Negative attitude	0.21 ± 3.26 %	0.39 ± 1.52 %	3.29 ± 28.16 %	7.80 ± 1.58 %
Positive attitude	0.34 ± 1.93 %	0.38 ± 2.84 %	3.94 ± 4.98 %	8.06 ± 2.06 %
Pain tolerance				
Negative attitude	38.96 ± 22.94 %	82.51 ± 3.3 %	208.02 ± 5.93 %	299.55 ± 3.67 %
Positive attitude	42.97 ± 4.86 %	74.19 ± 1.93 %	137.50 ± 2.36 %	288.45 ± 2.81 %
Corrugator activity				
Negative attitude	6.53 ± 4.78 %	13.03 ± 1.55 %	25.11 ± 7.61 %	37.76 ± 2.21 %
Positive attitude	6.65 ± 2.07 %	12.78 ± 2.11 %	18.04 ± 4.38 %	38.45 ± 1.54 %
Masseter activity				
Negative attitude	41.74 ± 2.49 %	20.76 ± 2.49 %	19.43 ± 3.58 %	17.29 ± 3.96 %
Positive attitude	15.56 ± 2.38 %	20.91 ± 1.84 %	12.49 ± 2.75 %	17.92 ± 1.51 %

Full model: condition (person ≠ alone ≠ dog). P = A model: person = alone ≠ dog. D = A model: person ≠ alone = dog. IA = interaction.

Table 6
Study 2 Subjective-verbal level of pain.

Model	1: Full model/null model	2: Full model/P = A model	3: Full model/D = A model	4: P = A model/D = A model
Bayes factor				
Rating after 30 s ^a	3.41 ± 0.75 %	2.32 ± 1.76 %	14.15 ± 1.16 %	6.09 ± 2.11 %
Rating after immersion ^b	1.13 ± 0.63 %	0.31 ± 1.29 %	3.51 ± 1.8 %	11.44 ± 2.21 %

Full model: condition (person ≠ alone ≠ dog). P = A model: person = alone ≠ dog. D = A model: person ≠ alone = dog.

^a N = 46.
^b N = 46.

problem even in a less ambiguous and clearer support context. In sum, even though unfamiliar persons had an analgesic effect, it was overall smaller than the dog's analgesic effect and did not extend to increased feelings of self-efficacy and less evaluation. Thus, evaluative threat seems a key component that can explain why dogs are better support

Table 7b
Study 2 Moderator analyses: Subjective-verbal level of pain (separate analyses).

Model	1: Full model/null model	2: Full model/P = A model	3: Full model/D = A model	4: P = A model/D = A model
Bayes factor				
Rating after 30 s				
Low negative attitude	18.41 ± 0.46 %	1.84 ± 1.35 %	71.10 ± 1.13 %	38.69 ± 1.76 %
High negative attitude	0.21 ± 1.08 %	0.77 ± 1.62 %	0.46 ± 3.84 %	0.59 ± 4.17 %
Low positive attitude	0.15 ± 1.34 %	0.52 ± 1.54 %	0.47 ± 2.52 %	0.90 ± 2.95 %
High positive attitude	49.70 ± 0.43 %	5.49 ± 0.75 %	162.08 ± 1.25 %	29.55 ± 1.46 %
Rating after immersion				
Low negative attitude	2.91 ± 0.45 %	0.38 ± 0.85 %	7.69 ± 2.41 %	20.00 ± 2.56 %
High negative attitude	0.13 ± 0.94 %	0.49 ± 1.59 %	0.47 ± 1.95 %	0.97 ± 2.52 %

Full model: condition (person ≠ alone ≠ dog). P = A model: person = alone ≠ dog. D = A model: person ≠ alone = dog.

Table 7a
Study 2 Moderator analyses: Subjective-verbal level of pain.

Model	1: Full model with IA/P = A model with IA	2: Full model without IA/P = A model without IA	3: Full model with IA/D = A model with IA	4: Full model without IA/D = A model without IA	5: P = A model with IA/D = A model with IA
Bayes factor					
Rating after 30 s					
Negative attitude	1.31 ± 9.78 %	1.88 ± 6.52 %	43.91 ± 8.9 %	10.74 ± 6.79 %	33.47 ± 13.22 %
Positive attitude	2.07 ± 8.63 %	2.08 ± 4.98 %	100.81 ± 5.78 %	10.78 ± 5.87 %	48.65 ± 10.39 %
Rating after immersion					
Negative attitude	0.13 ± 13.64 %	0.30 ± 13.55 %	9.07 ± 4.69 %	2.98 ± 4.91 %	71.58 ± 14.43 %
Positive attitude	0.11 ± 40.6 %	0.27 ± 4.23 %	0.85 ± 67.19 %	2.77 ± 5.22 %	

Full model: condition (person ≠ alone ≠ dog). P = A model: person = alone ≠ dog. D = A model: person ≠ alone = dog. IA = interaction.

givers than humans. Nevertheless, the degree of bonding with the dog played also a role for its pain-attenuating effects.

As expected, participants in Study 2 had a somewhat less positive attitude towards dogs in general than participants in Study 1 had towards their own dogs. Overall, the positive effects of the dog's presence on self-reported pain and stress during the task were only present for those who had a clearly positive attitude towards dogs. For those who did not feel very attached or were somewhat concerned about dogs, dogs were not better support givers than humans. On the contrary, these participants showed more stress and reported more negative affect in the presence of a dog than a human. That is, for self-reports and physiological measures a positive relationship as proposed by the intimacy model of pain (Cano & Williams, 2010), seems necessary.

Yet, for pain behaviors, pain coping abilities, and positive affect, the positive effects found in Study 1 were replicated. Specifically, irrespective of their attitude towards dogs, participants demonstrated better adaptation to pain, exhibited less pain behavior, reported reduced helplessness and higher self-efficacy as well as experienced more positive affect when suffering pain in the presence of unfamiliar dogs compared to the presence of unfamiliar human companions. This difference between pain behaviors and pain reports suggests that the verbal level of pain is influenced by negative affect, which was also moderated by the wariness of dogs. Conversely, the motoric level of pain might be more influenced by individuals' pain-coping strategies.

4.1. Dog compared to human support also increases pain-coping abilities

As mentioned above, compared to the alone condition, only dogs

Table 8a
Study 2 Moderator analyses: Pain-coping measures and affect.

Model	1: Full model with IA/ P = A model with IA	2: Full model without IA/ P = A model without IA	3: Full model with IA/D = A model with IA	4: Full model without IA/D = A model without IA	5: P = A model with IA
Bayes factor					
Helplessness					
Negative attitude	23.52 ± 6.13 %	47.21 ± 1.93 %	2379.47 ± 4.57 %	2796.22 ± 21.54 %	
Positive attitude	36.29 ± 3.59 %	48.95 ± 1.79 %	1895.3 ± 4.78 %	3713.70 ± 3.42 %	
Self-efficacy beliefs					
Negative attitude	0.28 ± 5.78 %	0.66 ± 4.24 %	19.61 ± 6.13 %	43.35 ± 4.44 %	
Positive attitude	0.67 ± 5.59 %	0.74 ± 4.09 %	27.26 ± 5.19 %	46.41 ± 3.75 %	
Positive affect					
Negative attitude	0.10 ± 4.5 %	0.23 ± 3.65 %	55.31 ± 4.61 %	51.41 ± 3.66 %	
Positive attitude	0.27 ± 3.84 %	0.24 ± 3.49 %	42.69 ± 4.38 %	53.65 ± 3.55 %	
Negative affect					
Negative attitude	4.66 ± 2.21 %	3.46 ± 1.98 %	445.44 ± 2.64 %	316.64 ± 6.62 %	95.56 ± 3.44 %
Positive attitude	2.22 ± 4.58 %	3.64 ± 2.71 %	350.52 ± 4.19 %	351.47 ± 3.56 %	

Full model: condition (person ≠ alone ≠ dog). P = A model: person = alone ≠ dog. D = A model: person ≠ alone = dog. IA = interaction.

increased participants' positive affect and self-efficacy beliefs, whereas human companions did not. This is in line with the conclusion of Che and colleagues (Che et al., 2018): Human social support mainly reduces acute pain by alleviating the perceived threat of the situation. Hence, it

Table 8b
Study 2 Moderator analyses: Pain-coping measures and affect (separate analyses).

Model	1: Full model/null model	2: Full model/P = A model	3: Full model/D = A model	4: P = A model/D = A model
Bayes factor				
Negative affect				
Low negative attitude	76.41 ± 1.04 %	0.33 ± 1.21 %	133.45 ± 1.49 %	405.95 ± 1.92 %
High negative attitude	3.23 ± 0.72 %	10.61 ± 1.68 %	1.86 ± 1.11 %	0.18 ± 2.01 %

Full model: condition (person ≠ alone ≠ dog). P = A model: person = alone ≠ dog. D = A model: person ≠ alone = dog.

Table 9
Study 2 Physiological level of pain.

Model	1: Full model/null model	2: Full model/P = A model	3: Full model/D = A model	4: P = A model/D = A model
Bayes factor				
Heart rate ^a	5.20 ± 0.76 %	17.09 ± 1.06 %	3.38 ± 1.09 %	0.20 ± 1.52 %

Full model: condition (person ≠ alone ≠ dog). P = A model: person = alone ≠ dog. D = A model: person ≠ alone = dog.

^a N = 43.

Table 10a
Study 2 Moderator analyses: Physiological level of pain.

Model	1: Full model with IA/ P = A model with IA	2: Full model without IA/ P = A model without IA	3: Full model with IA/D = A model with IA	4: Full model without IA/D = A model without IA	5: P = A model with IA
Bayes factor					
Heart rate					
Negative attitude	5.67 ± 4.07 %	10.43 ± 5.49 %	5.85 ± 4.19 %	2.38 ± 3.68 %	1.03 ± 5.84 %
Positive attitude	6.11 ± 3.96 %	10.44 ± 2.41 %	2.95 ± 3.89 %	2.53 ± 2.61 %	

Full model: condition (person ≠ alone ≠ dog). P = A model: person = alone ≠ dog. D = A model: person ≠ alone = dog. IA = interaction.

Table 10b
Study 2 Moderator analyses: Physiological level of pain (separate analyses).

Model	1: Full model/null model	2: Full model/P = A model	3: Full model/D = A model	4: P = A model/D = A model
Bayes factor				
Heart rate				
Low negative attitude	27.33 ± 0.63 %	2.61 ± 1.41 %	91.33 ± 1.66 %	34.93 ± 2.18 %
High negative attitude	1.07 ± 1.06 %	2.04 ± 2.21 %	0.40 ± 1.33 %	0.20 ± 2.58 %

Full model: condition (person ≠ alone ≠ dog). P = A model: person = alone ≠ dog. D = A model: person ≠ alone = dog.

may be that (similar to the effect of human support on chronic pain), dog support not only reduces pain via decreases in perceived threat (due to their nonjudgmental nature) but additionally increases pain tolerance and decreases pain behaviors via increases in individuals' pain-coping strategies (Du et al., 2018; Geng et al., 2018; Mikula et al., 2018). That is, increased self-efficacy and reduced helplessness could be responsible for the positive effect of dogs on motoric-behavioral expressions of pain: Dogs depend on humans as humans have control over their wellbeing; thus the presence of a dog seems to have primed self-efficacy beliefs in participants (Van Houtte & Jarvis, 1995), which in turn helped them to start feeling pain later, endure pain longer and show less facial displays of pain. In fact, previous research suggests that growing up with pets has beneficial effects on children's self-confidence (Van Houtte & Jarvis, 1995) and that highly self-efficacious individuals exhibit higher pain tolerance (Keefe et al., 1997; Litt, 1988; Schmitz et al., 2013).

4.2. Summary of the findings: own but also unknown dogs alleviate pain

To summarize, Study 1 showed that the presence of own dogs leads to lower self-reports of acute pain compared to the presence of close friends. Study 2 indicates that this 'dog effect' extends to unfamiliar dogs allowing the suggestion that close relationships and strong bonds to dogs are not necessary for dogs' analgesic impact. Dogs' non-evaluative and human-dependent nature may indeed suffice to make them more effective supporters than humans.

Nonetheless, the role of attitudes towards dogs cannot be neglected. Individuals with positive attitudes towards dogs experienced more pain relief from the presence of dogs; they reported feeling the least pain and exhibited the least physiological stress in the presence of a dog than in all other conditions and compared to those with less positive attitudes. Thus, results from Study 2 suggest that especially individuals with a positive attitude towards dogs appreciate their non-evaluative nature and feel supported by them.

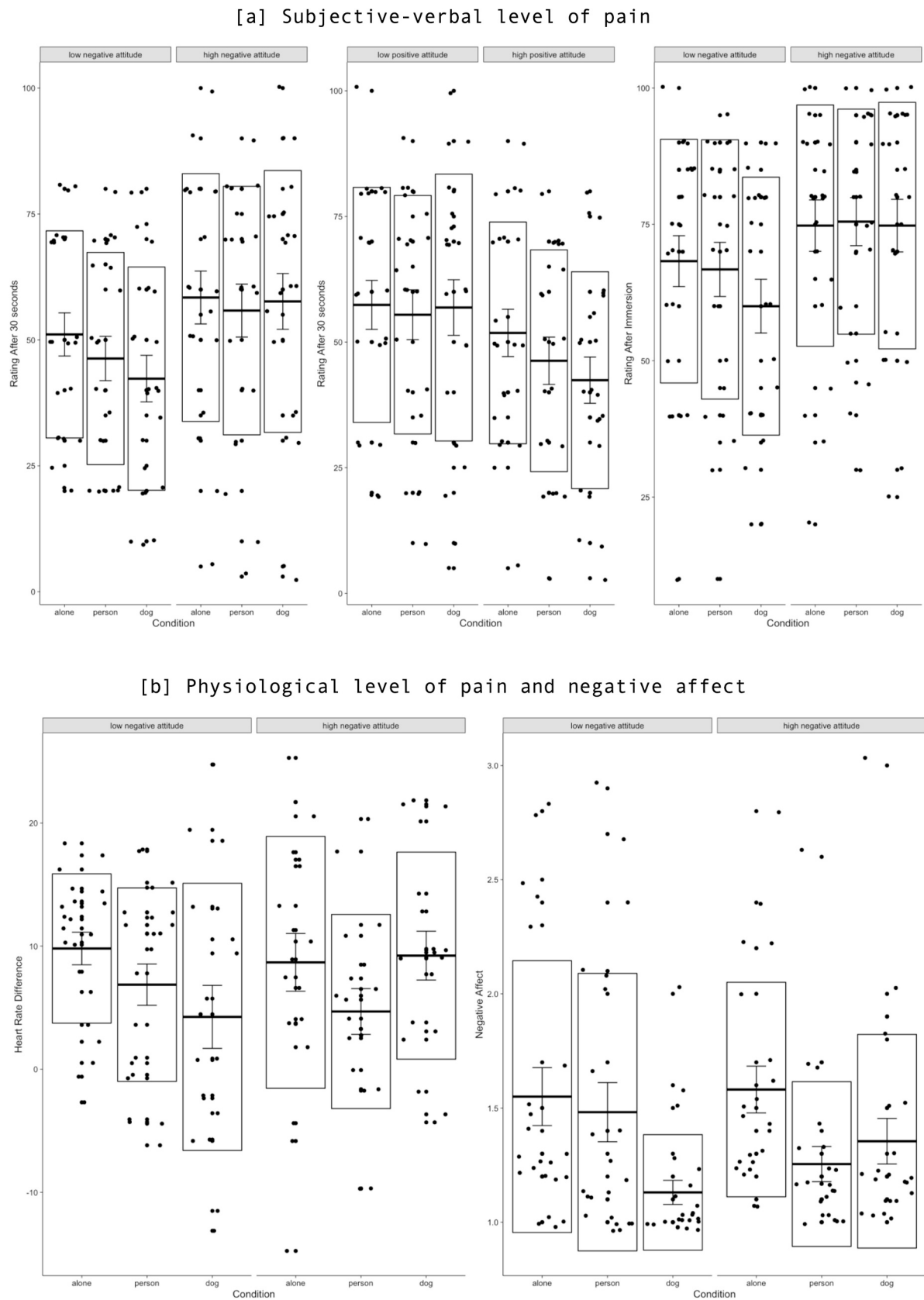


Fig. 3. Means, standard errors and distribution of the pain indices as a function of condition and affect (S2).
[a] Subjective-verbal pain indices as a function of the support condition and negative or positive attitudes towards dogs (if applicable) in Study 2.
[b] Physiological pain indices as well as negative affect as a function of the support condition and negative or positive attitudes towards dogs (if applicable) in Study 2.

Pain behaviors, however, were positively affected by a dog's presence—even for those whose attitude towards dogs is less positive. Hence, as manpower is costly and healthcare professionals often can only spend limited time with patients, it might be valuable to have dogs around people in pain. Further, dogs' self-efficacy enhancing effect could improve the quality of life in pain patients by reducing pain-related disability and depressiveness (Turner et al., 2005) and promoting health and healing processes (Bandura, 1991).

4.3. Strengths and limitations

The present research provides important new insights into the positive effects of a pet dog's presence during the experience of acute pain. Using a multivariate assessment of pain, we could show that compared to human companions, dog companions overall seem to be more effective pain relievers. The strong coherence of findings across the two different designs (unfamiliar versus familiar others, passive versus active support, between-subjects versus within-subjects design) suggests that the mechanisms revealed here are fundamental and may be valid for a range of different contexts. Specifically, they underline the power of dogs' presence in different types of non-clinical and clinical situations, such as for hospitalized children, for individuals who have to undergo surgery, or even for individuals with dental anxiety (Kaminski et al., 2002; Manley, 2016; Sobo et al., 2006).

A clear limitation of the present studies resides in the exclusively female sample. As pain-related behaviors are assumed to differ between women and men (Unruh, 1996), the present findings cannot readily be generalized to men. Further, our participants were relatively young and healthy and it is possible that the associations we found here may look different in other populations such as in the elderly or in chronic pain patients. Nevertheless, under the assumption that dogs are perceived as equally loving and supporting by men and women, young and old, healthy and unhealthy individuals, we expect to find similar effects for other populations.

Additionally, we used the cold-pressor task to evoke pain in participants and to measure the effect of dog versus human support on pain. Even though the cold-pressor task influences nociceptive nerves, it also activates other afferent sensory pathways and hence it leads to numbness and distress, which may replace the feeling of pain in certain circumstances. Further, reactions to the cold-pressor task may vary between individuals of different ages and between men and women, and up to date, there are no normative values for age and sex (Lamotte et al., 2021). Finally, there is evidence that some individuals can tolerate prolonged cold-pressor testing without any significant signs of physiological stress, which may distort the effects of experimental manipulations on the perceptions during the cold-pressor task (Lamotte et al., 2021). Nevertheless, the cold-pressor task is a widely used and validated procedure to experimentally induce pain and hence it fully met the requirements of the present studies.

Finally, it is important to note that findings in experimentally evoked pain studies may not readily translate to analgesic effects in chronic pain patients. A temporary pain induction cannot accurately reflect the various complex physiological and psychological changes that are associated with the experience of chronic pain. Still, experimentally evoked pain studies are useful to examine the modulation of pain by social factors, as often one has only limited access to chronic pain patients, and/or it may be more convincing to recruit patients after feasibility studies have been done on healthy populations (Campbell et al., 2019).

4.4. Conclusion: dogs as safety signals in painful situations

The social support by pet dogs has been characterized as non-evaluative support provided regardless of social or cultural norms, or the personal attributes of their owners (i.e., appearance, performance, personality, or socioeconomic status, Pachana et al., 2011; Walsh,

2009), hence we expected that this type of support may be more efficient in alleviating pain than the potentially evaluative support of a human companion. Both of our studies speak in favor of this notion. Together the studies suggest that dogs are better support givers during painful situations than their human counterparts. Yet, this effect is moderated by people's attitudes towards dogs, perhaps similarly to how attitudes towards human relationships mediate the effects of partners on pain (Hurter et al., 2014; Krahé et al., 2015; Sambo et al., 2010). Dogs may not act as safety signals and thus do not reduce pain when people are wary of dogs. Nonetheless, overall participants felt the least pain and exhibited the least pain behaviors in the dog condition suggesting that even for those with a warier attitude, dogs can be supportive. Specifically, dogs were able to increase pain coping mechanisms such as self-efficacy beliefs in a painful situation and thereby may have made individuals less sensitive and more resistant to pain. Although one should be cautious when extrapolating from experimentally induced to clinical pain, these findings may imply that strengthening social support provided by pet dogs could contribute to the well-being of suffering patients in addition to conventional means of pain management used in clinical and non-clinical settings (Calcaterra et al., 2015).

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.actpsy.2024.104418>.

CRediT authorship contribution statement

Heidi Mauersberger: Writing – review & editing, Writing – original draft, Visualization, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Anne Springer:** Writing – review & editing, Resources, Funding acquisition, Conceptualization. **Aikaterini Fotopoulou:** Writing – review & editing, Funding acquisition. **Christophe Blaison:** Writing – review & editing, Supervision, Methodology. **Ursula Hess:** Writing – review & editing, Validation, Supervision, Software, Resources, Project administration, Methodology, Funding acquisition, Conceptualization.

Declaration of competing interest

None.

Data availability

All data files from all studies are available on OSF: <https://osf.io/ykte3/>.

Acknowledgments

The authors wish to thank Christina Berger, Maureen Karcher, Eva Rosenberger, Teodora Zaharieva, and Benjamin Berstecher for their help with the data collection.

Financial Disclosure/Funding

This research was supported by a grant from the Volkswagen Foundation, in the context of their 'European Platform For Life Sciences, Mind Sciences, And The Humanities', to Anne Springer (# AZ II/85161) and Aikaterini Fotopoulou (II/85 069) for the Project 'Love Hurts: The Social Modulation of Pain.'

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