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# Timmy's in the Well: Empathy and Prosocial Helping in Dogs

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# Timmy's in the Well: Empathy and Prosocial Helping in Dogs

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# Abstract

Dogs are thought to empathetically evaluate humans' emotional states, and attend more to crying people than humming people (Custance & Mayer, 2012). However, whether dogs are empathetically motivated to provide help to humans in need is unclear. This study used a trapped-other paradigm, modified from use in research on rats, to study prosocial helping in dogs (Ben-Ami Bartal et al., 2011). A human trapped behind a door either cried or hummed, and the dog's behavior and physiological responses, including opening and distress behaviors and heart rate variability, were recorded. Then, dogs participated in an impossible task to evaluate the strength of their emotional bond with their owner (D'Aniello et al., 2015). This study found that dogs can help humans. Dogs in the distress condition opened at the same frequency, but significantly more quickly, than dogs in the neutral condition. Behavioral coding suggests that opening may have been motivated by different mechanisms in the distress and neutral conditions. Openers in the distress condition may have been motivated by an empathetic evaluation of the owner's emotional state with sufficient suppression of one's personal distress. In the neutral condition, opening was not related to the emotional response and may have instead been motivated by curiosity or a desire for social contact. Results from the impossible task suggest that dogs with strong bonds to their owner are more likely to behave empathetically toward them, which is consistent with the tendency of empathy to increase with familiarity (Cialdini et al., 1997).

*Keywords*: empathy, prosocial, heart rate variability

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Group survival in social organisms is dependent on prosocial behavior and empathy because they facilitate sociality, where animals’ abilities to interact, cooperate, and coordinate are contingent upon their ability to perceive and adopt each other’s emotional states (de Waal, 2008). Empathy is the emotional response that allows an individual to align their feelings with the feelings and experiences of another (Batson, 1998). An individual feeling empathy perceives the situation of another as though it were happening to them, which leads them to adopt a similar emotional state to the other (Preston & de Waal, 2002). According to the empathy-altruism hypothesis, this ability to adopt others’ emotions leads to altruistic helping, where actions are taken to increase someone else’s welfare (Batson, 1998). Some argue that empathy leads to ineffective helping because it can cause impulsive decisions if someone is overwhelmed by their empathetic concern (Bloom, 2016). However, sociality would not be possible at all if the members of a group could not comprehend or did not care about the emotional states of those around them. The ability to read social situations without relying heavily upon higher-order cognitive processes conserves cognitive energy in social animals, which allows for them to focus the majority of their cognitive functioning on other tasks without sacrificing their social competence (de Waal, 2008).

## The Evolution of Empathy

Empathy is believed to have evolved from simplistic mechanisms that facilitate group survival. For instance, reciprocal altruism is a basic behavioral pattern where animals are helpful to individuals by whom they have been helped in the past or from whom they can expect help in the future (Trivers, 1971). One of the intermediary emotional responses that likely evolved between altruistic helping and emotional empathy is emotional contagion. In emotional contagion, affective states are spread from an individual to those around them (Preston & de Waal, 2002). Many species experience emotional contagion, including rats (e.g., Church, 1959; Panksepp & Panksepp, 2013), pigs (Reimert, Bolhuis, Kemp, & Rodenburg, 2013), birds, and chimpanzees (Plutchik, 1987). Although primitive mechanisms resembling emotional contagion are found in other species such as ants (Hollis & Nowbahari, 2013), the form it takes in mammals is theorized to have become increasingly important in the development of the mother-infant bond. In particular, improving the emotional connection between mother and infant increases mothers' responsiveness to their infants' needs. This has been documented in both apes and humans (Hatfield, Cacioppo, & Rapson, 1993; Potegal, 2000; Preston & de Waal, 2002).

One way to estimate a species' capacity for emotional contagion is by evaluating their susceptibility to contagious yawning. Yawning in response to another individual yawning is considered an empathetic response because it is closely related to an individual's ability to infer the mental states of others, at least in humans (Platek, Critton, Myers, & Gallup, 2003). Contagious yawning is found in a variety of mammals, including chimpanzees, rats, and dogs (Campbell & de Waal, 2011; Joly-Mascheroni, Senju, & Shepherd, 2008; Moyaho, Rivas-Zamudio, Ugarte, Eguibar, & Valencia, 2015). Contagious yawning is likely related to the social bond between individuals. Endogenous opioids, neurotransmitters that are involved in social bonding (Panksepp, 1998), appear to be involved in yawning as well. Both opiate withdrawal and the administration of an opioid antagonist lead to an increase in yawning (Judson, Himmelberger, & Goldstein, 1980), indicating that there is a shared underlying neural mechanism between sociality and yawning.

Although there is considerable debate about the purpose of yawning, in some animals it is believed to serve as a social signal. In dogs, yawning is often considered a sign of stress (as reviewed by Mariti et al., 2012), while in primates, a yawn can also serve as a threatening gesture (Hadidian, 1980). Therefore, there is reason to believe that yawning delivers socially-relevant information. Contagious yawning may have evolved as a rudimentary mechanism for group synchronization, where individuals are better equipped to face environmental dangers if they can take cues from their groupmates about how best to respond to a situation. Empathetic responding may have developed from there as a means of better understanding the intentions of other group members, which enhances odds of survival even further. The perception and adoption of another's mental and emotional state at a basic level constitute the empathetic emotional response. Because contagious yawning is seen in a wide variety of species, many animals show the behavioral potential for an empathetic capacity.

Empathy evolved from contagious yawning because synchronizing with one's group facilitated group responses to survival-relevant stimuli. Because the usefulness of empathy is derived from its role in sociality, relationships play a role in the empathetic experience. For instance, empathy is highest when the subject knows the object for whom they are experiencing empathy. In humans, this in-group bias means that people tend to empathize more easily with close friends than strangers, and with people who they perceive as similar to themselves compared to people who seem very different (Cialdini, Brown, Lewis, Luce, & Neuberg, 1997). Further, familiarity interacts with the severity of the help-requiring situation, where relational closeness has an even more pronounced impact in situations of high need than in situations of low need (Cialdini et al., 1997). People are significantly more likely to empathize with and provide help for their loved ones when the situation is dire than when it is less urgent, but for strangers, an increase in a need for help does not increase the intensity of the empathetic experience to the same degree. This makes evolutionary sense: situations that require help-giving more urgently are also likely to be more dangerous for the intervening individual, so the likelihood of survival decreases for individuals who go out of their way to help strangers. In order to pass on one's genes, it is advantageous to help one's family to survive, and this would be facilitated by more empathy and help-giving in higher stakes situations (Cialdini et al., 1997). Far from being a human peculiarity, the tendency to experience empathy to a higher degree for familiar individuals is widespread among social animals.

## Empathy in Primates

Extensive research on non-human primates demonstrated that they may show many similarities to humans in their empathetic capacities. As previously mentioned, chimpanzees yawn contagiously in response to the yawn of a conspecific (Campbell & de Waal, 2011). Rhesus macaques will resist the temptation to take food if that action will also lead to the shocking of another macaque (Wechkin, Masserman, & Terris, 1964). Conflict resolution in chimpanzees also involves a degree of empathetic emotionality. In protective intervention, spectator chimpanzees intervene and protect the individual being aggressed against in a fight. This indicates not only that chimpanzees understand dominance hierarchies, but also that they can infer their conspecific's emotional state and use this information to differentially provide physical and emotional support to an individual that would otherwise suffer as a result of the conflict (as reviewed by Flack & de Waal, 2000). Female chimpanzees have even been shown to enter a tunnel containing a dominant male when experiencing an attack by other group members because the male would reliably emit a threatening vocalization that scared away her attackers. The authors' claimed that the male chimpanzee's apparent willingness to protect a weaker female by vocally coming to her defense may have indicated that he was discerning and responding to her fearful emotional state when he acted to remove the aggressive individuals that were frightening her (as reviewed by Flack & de Waal, 2000).

Chimpanzees can even show help-giving behaviors across species. This was demonstrated using an "out-of-reach" task, where chimpanzee performance could be compared to the performance of human children as young as 18 months of age on the same task (Warneken & Tomasello, 2006). In this task, an adult human dropped an object and alternated gaze between the object and the subject, who was either a chimpanzee or an infant, to see whether the subject would pick up and hand the object back to the experimenter. The chimpanzees, like the human children, helped a human who indicated their need for assistance (Warneken & Tomasello, 2006). Although this task does not explicitly require that the chimpanzee experience empathy in order to provide help, it does demonstrate that some animals may be able to perceive and interpret a human's intent and desire and respond to aid a person in the pursuit of their goal.

## Empathy in Rats and the Trapped-Other Paradigm

Rats are another social animal with documented prosocial behaviors. For instance, rats show cooperative problem solving. This was demonstrated in an experiment where two rats would alternate positions, where one rat would eat food while the other stood on a button in order to prevent a shock from being administered, thus allowing both rats to feed without being shocked (Daniel, 1942). Further experimentation demonstrated that pre-training to familiarize the rats with the experimental set-up was not necessary in this experiment. Rats would in fact acquire the cooperative behavior if the situation were novel to both rats when they were placed in it together (Rosenbaum & Epley, 1971). Beyond cooperation, rats also have been documented showing empathetic behaviors. The most basic form of empathy, emotional contagion, has been seen in both rats and mice (Panksepp & Panksepp, 2013).

Empathy and prosocial helping in rats has been tested through the use of various iterations of a trapped-other paradigm, where one rat can try to free another that is physically constrained. Altruistic helping behavior toward a trapped rat has been demonstrated in an experiment involving suspended rats, where rats pressed a lever to lower a hanging conspecific to the ground and reduce its distress (Rice & Gainer, 1962). However, rather than being truly altruistic, this “helping” behavior may have instead been motivated by a desire to remove personal distress caused by the distress behaviors and vocalizations performed by the hanging rat. This would then be a negative reinforcement paradigm rather than a test of empathy, where the “helper” rat learns to press the lever because it removes the aversive stimulus.

More recently, the trapped-other paradigm has been refined. In the newer version of the experiment, a rat was contained in a clear plastic restraining tube, and could be released if a door on the end of the tube was opened from the outside (Ben-Ami Bartal, Decety, & Mason, 2011). A free-roaming rat was placed into the arena containing either the restrained rat or a restrainer containing a stuffed rat, and their behavior was observed. This version is an improvement over Rice and Gainer (1962)’s iteration because rats make fewer distress vocalizations when trapped in a tube than when hung in the air, so it decreases the likelihood that the helping behavior would be acquired through negative reinforcement alone.

The free rat was shown to open the restrainer containing their cagemate rat more frequently than they would open one containing a stuffed rat. To evaluate the relative desirability of releasing one’s cagemate, an additional condition tested the rats in an arena with two restrainers, one containing a cagemate and one containing chocolate chips, which are a highly palatable treat for rats (Ben-Ami Bartal et al., 2011). The restrainer containing the cagemate was opened at the same frequency as the chocolate-containing restrainer. This indicates that the desire to open the restrainer containing the cagemate was sufficiently strong for the free rat, as the rat would open that restrainer even when another highly-potent reward was also available. In fact, rats even “shared” the chocolate from the other restrainer with their newly-liberated cagemate, with the free rat eating fewer chocolate chips after freeing the trapped rat than if there was not another rat present (Ben-Ami Bartal et al., 2011). The theory to explain this opening behavior was that the rats experienced an empathetic desire to reduce the distress of the rat that was trapped in the tube (Ben-Ami Bartal et al., 2011). After repeated exposures over multiple days, the rats learned to open the door with their heads rather than tipping it over with their sides, and stopped freezing when the door fell to the ground, which the author suggests means that the opening behavior became an intentional, goal-directed action (Ben-Ami Bartal et al., 2011). If the opening behavior was due to the distress of the trapped rat, it is still possible that the use of this paradigm mistook a negatively-reinforced behavior for an empathetic one, as the distress behaviors of the trapped rat might have been sufficiently aversive to motivate the free rat to open the restrainer in order to decrease them.

This helping behavior appears to be subject to the in-group bias. In a follow-up experiment, rats were first demonstrated to open less frequently and more slowly for rats of a different strain from their own (Ben-Ami Bartal, Rodgers, Bernardez Sarria, Decety, & Mason, 2014). Then, rats were reared in groups composed of individuals from strains different from their own (albino Sprague-Dawley rats were raised with black-caped Long-Evans rats). When tested in the aforementioned paradigm, Sprague-Dawley rats were more likely to help a Long-Evans rat, which was the strain with which the participant rat had been reared, than a Sprague-Dawley rat (Ben-Ami Bartal et al., 2014). This appears to indicate that social familiarity plays a greater role than genetic relatedness in a rat’s prosocial helping behaviors.

However, another study cast doubt upon the conclusion that the door opening behavior was motivated by empathy. A rival hypothesis to explain door opening was that the rats were opening the door out of a desire for social contact, where the free rat wants to be closer to the trapped rat, rather than out of an empathetic desire to help the trapped rat (Silberberg et al., 2014). Ben-Ami Bartal et al. (2011) demonstrated that the opening behavior was not extinguished when the experimental set-up was changed so that the restrainer opened into a separate compartment, meaning that the rats were further apart after opening. The authors claimed that this meant that the opening behavior could not be solely reinforced by social contact. Contradictorily, Silberberg et al. (2014) showed that rats would not acquire the opening behavior in the first place if social contact was never allowed after opening because opening the door released the trapped rat into an adjacent compartment. On later trials when social contact was allowed after opening, the opening behavior increased in frequency and decreased in latency, as predicted by the social-contact hypothesis (Silberberg et al., 2014). The lack of acquisition of the opening behavior when social contact was not satisfied brings into question this paradigm as a test of empathetic helping behaviors. Perhaps releasing the trapped rat into an adjacent compartment was sufficiently reinforcing that it maintained the opening behavior, but was not reinforcing enough to allow for its acquisition in the first place. The discrepancy in results between these two studies may mean that different mechanisms underlie the acquisition and extinction of prosocial behaviors, where social contact becomes increasingly irrelevant after a behavior has been learned.

Numerous problems with these studies lead to difficulty in interpreting their results. In the original study, for instance, rats would continue to open the restrainer for many days when there was no rat present in the restrainer (Ben-Ami Bartal et al., 2011). Clearly, opening the door of an empty restrainer is not an empathetic behavior. Further, because the door was initially challenging to open, rats in Ben-Ami Bartal et al. (2011)'s study had to be shaped through a starting condition of a partially-opened door on initial trials. This may have made the opening behavior more resistant to extinction once the opportunity for social contact was removed later in the experiment. On the other hand, no shaping was necessary in Silberberg et al. (2014)'s experiment because their restrainer was easier to open, as evidenced by the rapid acquisition of the opening behavior once the trapped rat could be released into the same chamber as the helper rat.

It is still possible that the opening behavior could have been empathetically motivated if the restrainer was distressing for reasons other than the restraint itself. Rats, which are highly social animals, may be as distressed by social isolation as by confinement. Opening to an adjacent compartment may have not only prevented social contact but also prevented the trapped rat's distress from being decreased as a result of the opening behavior. Because attempts to manipulate the emotional state of the trapped rat have been unsuccessful (Campbell, 2013), the trapped individual's experience of distress cannot be wholly separated from the free rat's desire for social contact. Therefore, a true test of whether this paradigm involves empathetic helping would require a direct manipulation of the trapped individual's emotional state, where there is variation in whether the trapped individual is distressed or not. If the opening response were empathetically motivated, the helper rat would only open the door if the trapped individual were distressed; in the absence of distress, there would be no reason to open the door. Since this manipulation cannot be made easily in rats, a possible solution is to involve humans in the role of the trapped individual, since humans can be instructed to artificially adopt a neutral or distressed emotional state. Then, the paradigm could be more valid in its test for a species' capacity for empathetic responses towards humans. An ideal candidate for this cross species study is the domestic dog.

## Empathy in Dogs

Domestic dogs are a useful species for empathy research because they are social and show a high capacity for cooperative and prosocial behaviors. Dogs evolved from wolves, which must coordinate behaviors in order to successfully hunt and breed. Cooperative problem solving is considered a precursor to prosocial helping behavior, and dogs have a demonstrated ability to cooperate. For example, Bräuer, Bös, Call, and Tomasello (2012) demonstrated that dogs are able to coordinate their actions to receive food, even when only one of the two dogs could receive a reward for their cooperation. To receive the reward, one dog had to stand on one side of a door such that the other side would be opened, leaving an opening through which the other dog could pass to retrieve the food. This experiment illustrated that, like hunting wolves, dogs are capable of cooperating in the pursuit of food, even when the food reward was not shared equally by all parties (Bräuer et al., 2012).

Dogs also have a remarkable capacity for responding to human social cues (Hare, Brown, Williamson, & Tomasello, 2002), and this capacity far exceeds wolves' even if they have been comparably socialized with humans (Miklósi et al., 2003). Rather than due to exposure alone, dogs' ability to use human social cues to reliably prompt behavior is the result of a long history of interspecies contact through domestication (Hare et al., 2002). The domestication of the dog was obviously beneficial for humans, as dogs assist humans in a wide variety of contexts including helping with hunting, search and rescue, and by guiding people with visual impairments (Quervel-Chaumette, Mainix, Range, & Marshall-Pescini, 2016). In order to fill these rolls, dogs had to acquire convergent socio-cognitive abilities with humans', looking to humans for information and interpreting human personal and social stimuli such as pointing (Hare et al., 2002). In return, humans provided dogs with protection and food. The social skills acquired during domestication allow a dog to understand something about a human's mental and emotional state, setting the stage for interspecific emotional contagion and empathy that would be highly beneficial for both humans and dogs.

Dogs' empathetic capacities towards humans have been investigated in a variety of situations. Like humans, dogs experience a contagious yawn response (Romero, Konno, & Hasegawa, 2013). Dogs yawned more following the presentation of a human face that was actually yawning than in response to one making controlled mouth movements that resembled a yawn. This indicates that dogs were experiencing yawn contagion in response to the exertive stimulus of yawning itself, rather than responding just to the mouth movements associated with yawning (Romero et al., 2013). Yawning can be a stress response in dogs, although dogs' heart rates did not increase when they yawned contagiously, indicating that this response appears to be unrelated to stress (Romero et al., 2013). Contagious yawning in dogs is also subject to an in-group bias. Dogs yawned more in response to their owner's face yawning than an unfamiliar one, which aligns with the expectation that empathy in dogs would be affected by emotional proximity (Romero et al., 2013).

Dogs also appear to be empathetic based on their reaction to a crying human. In a study to investigate dogs' ability to discriminate between human emotional states, individual dogs were placed in a room in their own home with two people, one of whom was their owner, and the other of whom was a stranger (Custance & Mayer, 2012). Both people hummed and cried at separate times. Therefore, approaches could be compared between conditions of both familiarity and distress, where an increase in approaches to the distressed person would imply that they were having an empathetic response. As expected, dogs approached the humans more often if they were crying than if they were humming, supporting the claim that they can empathetically respond to human distress.

An alternative theory to explain their seemingly-prosocial behavior is that dogs approach humans because they are egoistically seeking a decrease in the personal distress that they experience as a result of close proximity to a distressed human. This would be supported by an increase in a dog's approaches in the crying condition, but only toward their owner regardless of which person were crying. However, dogs consistently approached the person who was crying, even if it was the stranger, rather than always approaching their owner. This supports the claim that the approach behavior was motivated by empathy rather than a desire for a reduction in personal distress (Custance & Mayer, 2012). An alternative explanation for the pattern of responding found in this study could be that the dogs were curious about the human crying while not being curious about the humming, which caused them to approach the crier more often. However, this explanation is unlikely because 13 out of the 15 dogs acted submissively during their approach to the crying person, meaning that they were displaying behaviors consistent with mild worry or concern (Custance & Mayer, 2012). Had dogs merely been curious about the crying display, they would have been more likely to display behaviors consistent with a playful, alert, or calm affect (Custance & Mayer, 2012). The emotional valence of their approach behaviors indicates that dogs were doing so out of empathetic concern for the crying person rather than curiosity.

**Prosocial Helping in Dogs**

Although not necessarily motivated by empathy, dogs helping behaviors towards humans have also been investigated in-depth, and provide support for the idea that dogs are able to interpret human intentions. One study looked at whether dogs would press a button to open a door when a human wanted it to be opened (Bräuer, Schönefeld, & Call, 2013). Dogs were first shaped to press a button on the floor, and eventually received treats from the room beyond the door when the button was pushed and the door was opened. Then, dogs were tested to see whether they would open the door when there was a human in the room. The human either ignored the dog and read a booklet, or communicated to varying degrees a desire to get into the room beyond the door (by staring or pointing at the door, commanding the dog to open the door, or trying to get past the door into the room beyond). Dogs were more likely to open the door if they understood the human's goal. That is, they pressed the button most frequently when the person tried to get past the door, and opened at a lower rate when the person pointed; they were much less likely to open it when the human just stared at the door (Bräuer et al., 2013). While not directly involving empathy, this study highlights the important point that dogs may be able to help a human only if they understand that the human desires help, and if the help-giving behavior is well within their typical behavioral repertoire.

Other evidence suggests that the scope of dogs' empathetic and prosocial helping capacities is limited. In one study, a person simulated an emergency situation, such as a heart attack or being stuck under a fallen bookshelf, in the presence of a dog (Macpherson & Roberts, 2006). Help-giving in this experiment was operationalized as any attempt to make contact with or solicit aid from the bystanders who were also present in the experimental arena. Dogs did not seek bystander assistance, nor did they even appear to attend very much to the distressed person (Macpherson & Roberts, 2006). This appears to indicate that dogs do not empathetically respond to a human's distress in a help-requiring situation. Upon further examination, though, there are problems with this paradigm. For instance, the dogs did not appear to understand the nature of the situation, and thus were unlikely to have interpreted the situation as an emergency (Macpherson & Roberts, 2006). This is especially possible if dogs use external emotional cues to assist in the evaluation of appropriate situational affect. They may have interpreted the passive bystanders' lack of distress as people would in previous studies on the bystander effect: as an indicator of a non-emergency situation (Latané & Darley, 1968). Group inhibition occurs when a group does not react to a potentially-distressing event because each individual assessed the other individuals to be non-reactive, leading to an overall suppression of the distress response. In humans, this has been demonstrated by an individual's suppression of their concern about the presence of smoke in an experimental room if non-reactive experimental confederates are present (Latané & Darley, 1968). Similarly, dogs in this study may have evaluated that the trapped or injured person was not in need of assistance because they read the social cues of the bystander, who was not attending to them or acting distressed. Further, the requirement that prosocial helping was only evaluated to have occurred if it was in the form of the solicitation of bystander assistance is also problematic. Not only would dogs have had to overcome the suppression of their reaction that they would have likely undergone as a result of their evaluation of the bystander's emotional state, but they would have also needed to attempt to solicit assistance from someone who appeared to show no interest in providing help despite clearly being able to see the situation.

Other studies have had similar difficulty finding evidence of helping behaviors in dogs. Quervel-Chaumette et al. (2016) were specifically interested in looking at the prosocial helping behaviors dogs would display towards humans if they were not commanded to do a behavior. To parse helping behaviors from obedience responses, they compared helping behaviors towards dogs and towards humans using the same paradigm. Importantly, the humans were not allowed to communicate with the dogs in any way during testing. The dogs first learned that pulling on a lever would cause a baited tray to enter their enclosure, such that they would receive a treat reward. In the testing phase, pulling the lever would result in the baited tray entering a compartment that contained either another dog or a human. While dogs would pull the lever to provide food to a conspecific, they did so significantly less often for the human, regardless of whether they were familiar or a stranger (Quervel-Chaumette et al., 2016). Notably, dogs spent significantly more time staring at a human partner than at a conspecific. Gazing behavior may have been an attempt by the dog to assess the intent or desires of their partner. If dogs were looking toward their human for instruction or some indication of intent, they would necessarily gaze longer as they continued to wait for their unresponsive partner to communicate. In contrast, the canine partners in this experiment were not behaviorally constrained and might have communicated their desire for the food to the subject dog, so that dog would have not needed to continue gazing and waiting. Although the comparison of behavior towards humans and dogs allowed for the disentanglement of prosocial helping from obedience, it is unclear whether the comparison of helping between dog and human partners is valid, since canine confederates were likely still communicating with the subject dog in some capacity. Perhaps the results of this study suggest that dogs were showing empathetic helping responses to their fellow dogs because the dogs were communicating information about intent and emotionality while the human participants were not, and that humans must offer some sort of socially-relevant stimulus if dogs are to be expected to react empathetically or provide help to them.

## Heart Rate Variability

Because of challenges with the interpretation of previous studies on empathy and prosocial helping in dogs, future research must use a help-giving definition that is consistent with the dog's natural behavioral repertoire. Further, because empathy is an emotional experience, physiological measurements of distress and arousal would complement behavioral observations in order to more fully understand the emotional experiences that dogs undergo during tests designed to solicit empathetic distress. Physiological measures can be more sensitive to subtle changes in emotional valence than behavioral observations, and because animals cannot report their emotional state, they may allow for more nuanced claims about the nature of the empathetic response and its limitations.

One such physiological measurement is Heart Rate Variability (HRV). HRV is a measure of the beat-to-beat fluctuations in heart rate. The intervals between heart beats decrease in length as heart rate increases, and thus HRV is a measure of how rapidly and flexibly an individual can shift between different heart rates. The heart is innervated by the vagus nerve, which regulates heart rate through interactions with the heart's primary pacemaker, the sinoatrial node (Appelhans & Leucken, 2006). The relative activation of sympathetic and parasympathetic (vagal) impulses in cardiac tissue antagonistically interact to determine heart rate (Appelhans & Leucken, 2006). In opposition to the sympathetic nervous system, which controls physiological arousal and excitation, the vagus nerve sends inhibitory impulses to cardiac muscle, resulting in a decrease in heart rate and return to homeostatic equilibrium following a period of excitation (von Borell et al., 2007). Rapid shifts in heart rate are always vagally mediated, and are preceded by changes in vagal nerve stimulation by about five seconds, whereas the influence of the sympathetic nervous system can take up to 30 s to take effect in the heart (von Borell et al., 2007). Because the response in cardiac tissue to its impulses is relatively rapid, the vagus nerve is responsible for the fine-grained changes between interbeat intervals captured in HRV.

The distribution of brain regions responsible for physiological changes in response to emotional and situational cues is known as the central autonomic network (CAN), which includes cortical, limbic, and brainstem regions (Appelhans & Leucken, 2006). The CAN outputs directly to the sinoatrial node via the vagus nerve, such that changes in heart rate are dictated directly from these brain regions. In return, information about HRV is related back to the CAN, forming a feedback loop between the central nervous system and peripheral components (Thayer & Friedman, 2002). The CAN is thought to be primarily responsible for an individual's capacity for emotional regulation, their control over mental and physical responses to emotional stimuli (Appelhans & Leucken, 2006). The inhibition transmitted by the vagus nerve allows systems to function efficiently when faced with unexpected internal or environmental cues (Thayer & Friedman, 2002). Because of the relationship between the CAN and emotional regulation, changes in heart rate reflect changes in emotional state and emotional regulation capacity (Appelhans & Leucken, 2006).

A large amount of variation between subsequent beat-to-beat intervals is considered healthy, whereas a low amount of HRV is seen in stressful situations or in individuals who have experienced chronic stress (von Borell et al., 2007). Variation in trait HRV predisposes individuals to different amounts of emotional and physiological reactivity. In farm animals, HRV has been used to evaluate both well-being and temperament (von Borell et al., 2007). Vagal tone, which occurs when only the vagus nerve is determining an individual's resting heart rate, differs between individuals, and low vagal tone is related to anxiety, aggression, and behavioral problems in children (Fabes, Eisenberg, & Eisenbud, 1993). Therefore, it can serve as an approximate measurement of an individual's susceptibility to stress (von Borell et al., 2007). HRV is also related to the stress response itself. Stress activates the sympathetic nervous system, resulting in increases in heart rate, decreases in heart rate variability, and a decrease in the relative contribution of the vagus nerve to the determination of heart rate (von Borell et al., 2007).

Following from its relationship with stress, HRV can serve as a physiological measurement of an individual's emotional reaction to a situation. In fact, it can reflect an individual's capacity for emotional regulation. It is a measure for how flexibly cardiac activity can be modified in response to changes in situational conditions: beat-to-beat shifts in heart rate prepare an animal to quickly respond when a situation shifts, allowing them to be better prepared for unexpected changes in the environment (Appelhans & Leucken, 2006). Emotional regulation is important for typical functioning. A decreased capacity for emotional regulation as well as disturbances in heart rate regulation is associated with psychiatric disorders such as depression (Beauchaine, Gartner, & Hagen, 2000) and schizophrenia (Boettger et al., 2006). In both of these instances, decreased psychiatric functioning is associated with lower HRV.

That HRV can measure one's capacity for emotional regulation makes it relevant to the study of empathy, because empathy can only occur when one is able to regulate their response to an emotionally-salient event. A lack of empathetic emotional response occurs when an individual reacts to another's distress by feeling personal distress for themselves rather than empathy for the other (Batson & Oleson, 1991). This is particularly true when the easiest way to reduce personal distress is incompatible with an altruistic helping response. Sometimes, egoistic behavior can be misinterpreted as altruistic when the reduction of personal distress is most easily achieved through an empathetic response (Eisenberg & Fabes, 1990). Usually, however, the egoistic response is qualitatively different from the empathetic response, oftentimes involving avoidance and escape behaviors (Batson & Oleson, 1991). Importantly, experiencing distress in response to another’s stressful experience is necessary for empathy, but it results in egoistic responses rather than altruistic helping when personal distress is overwhelmingly aversive (Eisenberg & Fabes, 1990). Thus, the ability to suppress one’s personal emotional response is essential for empathetic action: one must be able to assess that someone else is distressed, but not become so affected by the distress that they are unable to provide help.

The physiological mechanism underlying this effect is one of optimal functioning under stress. The Yerkes-Dodson law states that performance is optimized at a moderate level of stress, where too little stress decreases motivation and too much stress inhibits functioning (Yerkes & Dodson, 1908). In the case of empathy, some stress must be induced by another’s distress, otherwise there will be no motivation to provide help. However, when this stress becomes overwhelming, helping is impossible and the individual focuses instead on returning themselves to a more comfortable state.

The relationship between empathy and emotional regulation has been behaviorally tested in human populations. A study on emotional responding in children defined sympathy as “an other-oriented response involving some vicariously-induced emotion,” and thus sympathy is interchangeable with empathy for the purposes of this study (Eisenberg & Fabes, 1990, p. 132). This study demonstrated that children who react to distressing situations but are better able to regulate their own emotional states are more likely to display sympathetic responses than those who are not able to control their reactions (Eisenberg & Fabes, 1990). To demonstrate this, preschoolers were shown a video of injured children in the hospital then were given an opportunity to either pack boxes of crayons for the hospitalized children or play with toys. Boys who displayed facial responses of sympathetic sadness (eyebrows flattened and pulled forward toward the nose, upper eyelids not tightened or raised, lower eyelids raised slightly, and head and body facing forward) while watching the video were more likely to act prosocially by packing crayons, whereas those who displayed facial expressions of personal distress consistent with anxiety and fear (eyebrows raised and pulled together; nonfunctional, nervous mouth and chin movements) were more likely to play with the toys and less likely to provide prosocial help (Eisenberg & Fabes, 1990). The facial indices of personal distress were also associated with increased heart rate, while sympathetic sadness and prosocial helping were associated with heart rate deceleration (Eisenberg & Fabes, 1990).

A similar study furthered the investigation into the relationship between emotional regulation and empathetic helping. In this study, children's reactions to an empathetically-distressing video were compared to measures of their emotionality, social functioning, and emotional regulation as judged by each child's teachers and parents (Eisenberg et al., 1996). Each child first watched an emotionally-neutral film about dolphins, then a distressing film about a child recovering after being injured in a fire. Following the distressing video, their empathetic capacity was tested using a puppet paradigm followed by an empathy-sympathy questionnaire. This study found that children were high in sympathy if they were high in both emotionality and emotional regulation (Eisenberg et al., 1996). This supports the idea that empathetic helping occurs when one is emotionally aroused by the presence of distressing social stimuli, but is also able to sufficiently regulate their own emotions and focus on the needs and emotional states of others.

Prosociality and empathy in children are also related to HRV. Fabes et al. (1993) investigated the induction of empathetic states in children using a similar protocol, where children's facial expressions were coded while they watched an emotional video. Following the video, the children were asked to report their emotional states by indicating to what degree they were experiencing a series of emotions related to personal distress (“feeling nervous or afraid”) and sympathy (“feeling sad;” Fabes et al., 1993). In this study, data on heart rate and skin conductance were also recorded while the child was watching the video. It was found that children who reported being distressed were more likely to avert their gaze during the video, to have high levels of skin conductance (a measure of physiological arousal), and to have lower HRV when compared to children who reported sympathetic emotions and did not avert their gaze (Fabes et al., 1993). This indicates that, in children, there is indeed a relationship between empathetic response and HRV. High HRV is generally related to a high capacity for sympathetic responding and low levels of personal distress. Low HRV, in contrast, is correlated with traits such as inhibition, shyness, and fearfulness, which may account for the decreased level of sympathy and increases in personal distress found in children with lower HRV (Fabes et al., 1993).

The relationship between emotionality and HRV has also been studied in dogs. Kuhne, Höβler, and Struwe (2014) compared heart rate and behavioral indices of discomfort when dogs were being pet by a stranger. It was found that dogs’ HRV was significantly lower when they were being pet by a stranger than when they were being pet by their owner. Further, low HRV was correlated with an increase in appeasement gestures, such as freezing or gaze aversion. This behavioral measure reinforces that dogs were experiencing discomfort when their HRV was relatively low, and that they desired to avoid what they perceived to be an increased chance of potential conflict (Kuhne et al., 2014). Therefore, HRV appears to be a good index for the arousal that results from emotionally-charged social situations.

It may be possible to infer dogs’ emotional states through indices of HRV. This was demonstrated through recordings of dogs’ heart rate during situations that were intended to elicit positive (getting pet by their owner), negative (social isolation), or neutral (in the same room as their owner, but their owner ignored them) affect (Katayama et al., 2016). Behavioral indices of stress confirmed that the manipulation was effective, as dogs were more likely to bark, whine, and attend to the door through which their owner had exited in the negative condition than during the neutral or positive conditions. Dogs were found to have lower HRV in the negative situation, such that the parasympathetic nervous system was less active than it was during the positive or neutral conditions (Katayama et al., 2016). HRV may therefore be a useful physiological measure of the canine emotional state. Because of the known connection between HRV and empathy, and because HRV has been shown to reflect emotional state specifically in dogs, it is an ideal measure to evaluate dogs' emotional responses as related to their prosocial helping behaviors.

## Present Study

This study sought to investigate empathy in dogs through a modification of the trapped-other paradigm that has previously only been used in rats (Ben-Ami Bartal et al., 2011). To test whether this paradigm is valid as a test of empathy, this experiment compared dogs' prosocial behaviors in the form of door-opening towards distressed and non-distressed humans. This experiment enables further inquiry into dogs' unique capacity for empathetic feelings toward humans. It does so by investigating whether dogs would not only differentially approach humans based on their emotional states, as demonstrated by Custance and Mayer (2012), but would in fact show a change in their help-giving behaviors based on a person's emotional display. It also tested the validity of a trapped-other paradigm as a measurement of empathy in animals, as the emotional display of the trapped-other was able to be directly manipulated with the use of human subjects. Humans could be instructed to adopt either a distressed or neutral affect, and if empathy were the sole driver of the opening behavior, it would only occur if the person trapped behind the door were distressed. This manipulation allows the influence of another's distress to be more explicitly tested. Further, the use of dogs as study subjects gives an opportunity for the quantification of the free animal's physiological experience during the task in order to better evaluate how personal distress and emotional suppression contribute to the presence or absence of an empathetic helping response.

In this experiment, a human confederate sat in a chair behind a clear door that could be opened through physical contact by the dog. The human behind the door either cried or hummed (Custance & Mayer, 2012). The number of dogs who opened, the speed with which they opened, their stress behaviors, and their heart rate variability during the task were recorded. This allowed for quantitative comparisons of prosocial helping toward a trapped other based on whether they appeared to be distressed. It was hypothesized that if dogs modulate their prosocial helping behaviors through empathetic evaluation of humans' emotional states, then dogs in the crying condition would open more often and more rapidly than those in the humming condition. Crying would also elicit more behaviors associated with negative affect than humming (Custance & Mayer, 2012). Alternatively, if opening frequencies and latencies did not vary by condition, this would indicate that dogs do not modulate their prosocial helping behaviors through empathetic evaluation of humans' emotional states. They may instead open the door out of curiosity or a desire to be nearer to their owner. The latter result would support the theory that releasing a trapped individual from a confined space may not actually involve empathy at all, but is instead motivated by a desire for social contact (Silberberg et al., 2014).

Dogs' HRV was recorded during the experiment to provide an independent measure of their emotional state. Baseline HRV was expected to correlate with opening rate. If HRV were a good predictor of dogs' empathetic responses, those with higher baseline HRV would open faster than those with lower HRV, because their ability to regulate their emotional response is correlated with empathetic capacity. However, if baseline HRV were lower in dogs who open more quickly, then HRV may not be a good measure for empathy in dogs, and may instead more accurately reflect their level of distress without the influence of the self-regulation factor as has been seen in children (Fabes et al., 1993). This could also indicate that anxious dogs, who have lower HRV, are more distressed by the experimental situation and seek emotional support and social contact from their owners to soothe their own distress (Eisenberg & Fabes, 1991; Silberberg et al., 2014).

Following the prosocial helping trial, each dog was tested using the impossible task paradigm to assess the strength of their emotional bond with their owner (D'Aniello, Scandurra, Prato-Previde, & Valsecchi, 2015). This task has been used as an index of emotional attachment between dogs and humans, as the dog's gaze duration toward a given human appears to be related to the strength of their emotional bond, where dogs with more extensive training stare more at their trainers than untrained dogs and kennel dogs look less at humans overall (D'Aniello et al., 2015; D'Aniello & Scandurra, 2016). Because empathetic responses are more likely to be shown towards familiar individuals with whom one is more strongly bonded (Cialdini et al., 1997), this task could be used to evaluate the degree to which the strength of a dog's emotional bond to their owner influences their empathetic responses to that owner. Each dog was first trained to knock over a jar to receive food that was trapped underneath, then was observed when the jar was made immobile. The dog's owner and a novel stranger were present in the room, although they did not move and looked away from the dog for the duration of the trial, which lasted for 60 s. The expectation was that the dogs who responded empathetically in the distress condition in the prosocial helping task would be the dogs that are more strongly emotionally-bonded with their owner, and would then also stare more at their owner during the impossible task than non-opening dogs.

# Method

## Subjects

The subjects were 39 (24 male, 15 female; 33 spayed or neutered) adult household dogs that live in the Twin Cities area in Minnesota, and that were volunteered by their owners. The dogs were adults (*M* = 6.5, *SD* = 2.6 years old), and they ranged from 1.5 to 12 years old. They ranged from 8 to 160 lbs (*M* = 46.5, *SD* = 28.6 lbs). There were a variety of breeds, although the most common types of dog were mixed breed (N = 13) followed by golden retriever (N = 5). There were also various spaniels, corgis, and huskies, among others. Because they were recruited as part of another study, about half of the dogs (N = 18) were nationally-certified therapy dogs, while the other dogs (N = 21) were non-therapy pet dogs. There were no differences between conditions with regards to age or weight, all *t*s < 1, all *p*s > .330, or sex, $\chi 2(1, N = 35) = .05$, $p = .826$. There were also 39 human participants (36 female, three male), one to accompany each dog during the experiment. The human participants ranged from 19 to 75 years old, with a mean of 49.6 years old. Subjects were recruited by word of mouth or from an ad in a daily email newsletter.

## Apparatus and Materials

A behavioral and demographic survey was used to obtain information about the owner's age, gender, and dog-owning history, and the dog's age, sex, breed, health history, and training.

To record the dog's Heart Rate Variability (HRV), a Polar H7 Heart Rate Monitor was used (Polar Electro, Kempele, Finland). The data from the monitor was transmitted via Bluetooth to an iPhone app (Heart Rate Variability Logger, Marco Altini). The HRV data was analyzed using ARTiiFACT software (Kauffman et al., 2011).

The testing arena was a rectangular room with a small square room adjacent to the main chamber (see Figure 1). There was a chair in the square room, and a small door separating the small room from the main one. The door (96.5 cm wide x 122 cm tall x 2.54 cm thick) was made of gray-painted wood, and a sheet of clear Plexiglas (55.9 cm x 106.7 cm) spanned the interior of the door to make a window (see Figure 2). This door was strongly attached to the door frame by three magnets positioned vertically along the hinged side of the door. The other side of the door was loosely connected to the other side of the door frame with three weak magnets positioned vertically, such that contact with the door by a dog's nose or paw allowed it to easily swing open into the small room. Pilot trials indicated that dogs of varying sizes could easily open the door.

The impossible task was performed in a small room that was across the hall from the prosocial task testing space. The apparatus involved a piece of wood (60.96 cm x 53.3 cm x 0.6 cm) that was covered in white fleece to prevent splinter injuries to the dogs. The wood had Velcro on the edges of its bottom side that allowed it to be securely attached to the carpeted floor of the room. At the center of the wood plank on the top side, the lid of a glass jar was glued upside-down, such that the jar could be screwed upside-down into its lid and would be immovable. This meant that anything placed onto the lid before the jar was screwed down would be visible but could not be reached.

## Prosocial Helping Task

Because it improves accuracy with the heart rate monitor and is necessary to improve motivation during the impossible task, owners were instructed to restrict their dog's access to food for four hours prior to testing (D'Aniello et al., 2015). After the owner consented to the experiment, a heart rate monitor was placed on the dog while the owner was in the room. Veterinary lubricant was applied to the monitor to enable conductivity before it was placed just left of center on the dog's chest, and was held by a band that was wrapped around the dog's ribcage to hold it in place. The band was adjusted to ensure that it was snug but not too tight. The connection between the monitor and the app was established, and a 10 minute period of baseline heart rate data was collected. Once the baseline heart rate data had been recorded, the owner went with one of the experimenters into the testing arena and instructed on their role in the prosocial helping portion of the experiment.

This procedure is a modified protocol of the trapped-other experiment with rats (Ben-Ami Bartal et al., 2011). The owner was seated in a chair in the small square room, and the small door to their room was closed such that they were separated from the main chamber by the door. Dogs were assigned to either the distress or neutral condition. This assignment was done by categorizing each dog into one of four groups based on size (small or large) and whether the dog was a therapy dog (therapy or non-therapy dog). In each of these categories, condition assignment alternated, such that within each of the four groups there were an approximately equal number of dogs assigned to each condition. Each owner was instructed on what vocalizations to make depending on what condition they were assigned. In the neutral condition, the owner said “Help” in a neutral tone every 15 seconds, and hummed “Twinkle Twinkle Little Star” between each iteration. In the distress condition, the owner said “Help” in a distressed tone at 15 second intervals at approximately the same volume as in the control condition, and made crying sounds between each iteration. In both conditions, the owner hid their hands from their dogs by placing them under their legs to prevent unintended communication with hand gestures and maintained their gaze slightly above the dog's eye level to decrease variation in the amount of eye contact between conditions.

The dog was brought into the room and positioned at the far end of the room from their owner and facing toward their owner. The experimenter released the dog's leash and left the room, at which point a timer was started. The timer was stopped if the dog touched the door and detached its magnets from the door frame, thus opening the door. In trials where the dog did not open the door, the experiment was terminated after 5 minutes. Each dog was allowed to reunite with their owner for a short period of time following the prosocial helping trial, regardless of whether they opened the door. Each trial was video recorded, and the videos were used to calculate latency to opening and coded to assess behavioral signs of distress in the dogs.

## Impossible Task

Following the prosocial helping task, the dog's owner left the room with an experimenter and proceeded to the next stage of the experiment while another experimenter stayed with the dog. In the impossible task, the dog's owner and a stranger stood on opposite corners behind the testing apparatus, which was positioned in the middle of the room on the floor. The side of the apparatus (left or right) that the owner stood on was counterbalanced across subjects. The owner and stranger each stared diagonally across the room and remained still throughout the experiment. Once the room was set up, the dog was brought in and held in the back of the room by an experimenter, approximately 0.5 m away from the testing apparatus, such that the dog could see the apparatus and the two people standing behind it.

The main experimenter started by giving the dog a treat to show them that there was an opportunity for food. Then, a treat was placed on the lid at the center of the wood plank, and the dog was released to go get the food. After it had eaten the treat, the dog was retrieved and brought back to its starting position. For the next three treats, the food was placed onto the lid of the jar, and the jar was placed gently on top of the lid such that it could be easily tipped over to retrieve the food underneath. The dog was released to retrieve each piece of food, and if it did not knock over the jar rapidly, the experimenter encouraged the dog to move the jar in order to retrieve the food. No dog was allowed to progress to the final trial until it had moved the jar to get to the food underneath three times; this ensured that dogs had started to acquire a jar-moving behavior in order to receive a food reward. In the final trial, the food was placed on the lid and the jar was screwed into place over it. The set-up looked identical to the previous trials, however this time the jar could not be moved even if the dog attempted to knock it over with a large amount of force. Once the jar was put in place, the dog was released and the two experimenters exited the room, such that the dog was alone in the room with their owner and the stranger. The trial lasted 60 s, during which time both heart rate data and videos were recorded for later analyses of HRV and gaze direction, respectively. After the trial period had passed, the experimenters re-entered the room and removed the jar so that the dog could eat the treat underneath. The heart rate monitor was then removed from the dog, and the owner was debriefed about the purpose of the experiment.

## Behavioral Ethogram

Dogs were videotaped for the duration of the baseline heart rate recording, and the prosocial helping arena and impossible task room were each videotaped from two different angles. In the prosocial helping arena, one angle allowed for view of the dog’s face when they were facing the door and looking at their owner, and the other allowed for a view of their movement through the experimental room. An ethogram was used to code videos for behavioral measures of stress during baseline and testing. Eight variables were recorded: vocalizing (barking or whining that was audible on the video, duration), panting (duration), sniffing the floor (duration), urogenital checkout (sniffing or licking, count), shaking off (count), yawning (count), scratching oneself (count), and flicking the tongue (count; as reviewed by Mariti et al., 2012). The video cameras could not be set up to capture the entire experimental arena, so the amount of time that the dog was visible in the video was also recorded for each trial. Because evaluation of vocalizations required auditory cues from the video, the video coder for the prosocial task was not able to be blind to condition (since the owner's vocalizations were also audible on the video) nor opening (since the length of the video indicated whether the dog opened or not, as all dogs that did not open had 300 s videos while openers had shorter videos). However, there was no difference in total distress behaviors between the distress and neutral conditions, indicating that experimenter-expectancy bias did not significantly influence the results. A separate experimenter completed the ethogram for the baseline stress behavior coding, and this coder was blind both to experimental condition and whether the dog opened the door during the prosocial task. In the impossible task, one camera faced the owner and stranger from the front, and the other was set up to record a side view of the experimental room. Videos of the impossible task were coded to compare gazes toward the owner and stranger as well as task-oriented behaviors such as digging at or attempting to move the jar to get to the food underneath. A separate experimenter from the two previously mentioned coded the impossible task videos.

## Data Processing

Behavioral coding was used to quantify dogs' distress during the baseline and experimental portions of the study. The individual totals of stress behaviors were summed to yield a total stress score for each dog. In order to ensure that trial length and visibility in the videos did not confound the behavioral distress measure, this value was then divided by the total amount of time, in seconds, that the dog was visible in the video during the experiment to yield a score of stress per second for each dog. The baseline behavioral recording period was 10 minutes for every dog (except for four dogs, for which the videos were unintentionally truncated), whereas the testing behavioral recording period was equivalent to the length of the trial (either the latency to opening, or 300 s for dogs that did not open). One dog was excluded from analyses on baseline stress behaviors because their video did not save properly, and thus stress behaviors could not be analyzed. Videos of the impossible task were coded for the amount of time that the dog spent gazing either at the owner or stranger, or performing task-oriented behaviors. The percentage of gaze that was directed at the owner was calculated by dividing the amount of time spent gazing at the owner over the total amount of time the dog spent gazing at either the owner or the stranger.

All heart rate data were analyzed using Artiifact (Kaufmann et al., 2011), which allows for detection and removal of heart rate measurement errors, also known as artifacts. There were four dogs that were excluded from heart rate analyses because a reliable connection was not able to be established during baseline or because the reading dropped during the prosocial trial. Analyses on heart rate variability (HRV) were performed on a total of 31 dogs (15 in the distress condition, 16 in the neutral condition). For the baseline sampling, only the most consistent five minute section of the file was used in analyses. If the entire file was consistent, seconds 180 to 480 were used. For the trial phase, the entire file was used unless there was enough inconsistency in a section to deem it unusable, in which case as much of the file as possible was selected. All inter-beat interval data points above 2000 ms were classified as artifacts and were removed from the sample prior to analyses, as this is a greater value than any true arrhythmia. Cubic spline interpolation was used to smooth the samples, which were then analyzed for a variety of measures of heart rate variability using Artiifact. The VLF band was set at 0.06 Hz, while the LF band was set at 0.24 Hz, and the HF band was set at 1.06 Hz (Houle & Billman, 1999). Although the software produces a variety of other heart rate variability measures, including mean HR, SDNN, RMSDD, NN50, VLF, LF, HF, and LF/HF ratio, pNN50 was used to quantify heart rate variability in analyses because it is less sensitive to sample length than the other measures, and the samples from the prosocial helping task varied in length from 4 to 300 s. pNN50 is a measure of the percentage of successive RR intervals which differ from each other by more than 50 ms, and thus a high pNN50 corresponds to high heart rate variability.

## Results

A total of 39 dogs participated in the experiment. Two dogs were excluded from analyses because they showed signs of aggression during pre-test monitoring, and were thus considered too anxious to be included. One dog was excluded because it was deaf and could not hear the sounds made by the owner during the trial, and thus was not effectively subjected to the experimental manipulation. One dog was excluded from analyses on opening rate and latency because the owner chose to end the trial before the five-minute trial length had been completed. Finally, one dog was excluded because its owner did not follow instructions and encouraged the dog to open the door, which led to opening. For the other 34 dogs, whether the dog opened and the latency to opening were recorded. If the dog did not open, latency was counted as the length of the trial (300 s). There was no difference between therapy dogs (9 opened, N = 16; average latency = 165.19 ± 140.33 s) and non-therapy dogs (7 opened, N = 18; average latency = 210.22 ± 119.93 s) in opening frequency, $\chi 2(1, N = 34) = 1.025$, $p = .311$. There was also no difference in latency to opening, and Levene’s test for homogeneity of variances was significant, $F = 4.99$, $p = .033$, so equal variances were not assumed, $t(29.74) = 1.00$, $p = .326$. Because of the lack of significant variation between them, all subsequent analyses were collapsed across therapy and non-therapy dogs.

**Helping**

Overall, helping occurred in about half of the trials (16 opened, N = 34). For dogs that opened, latency to opening ranged from 4 to 298 s (*M* = 64.19, *SD* = 75.75 s). There was no significant difference in opening frequency between the neutral condition (9 opened, N = 17) and distressed condition (7 opened, N = 17), $\chi 2(1, N = 34) = .472$, *p* = .492 (see Figure 3).

A T-test was used to compare latency to opening between conditions, which did not differ between dogs in the distress condition (*M* = 186.12 s, *SD* = 140.73 s) and dogs in the neutral condition (*M* = 191.94. s, *SD* = 122.46 s), *t*(32) = -.129, *p* = .898. However, when only dogs that opened were considered to remove the effect of all non-openers having equivalent latency, there was a significant difference in latency to opening between dogs in the distressed (*M* = 23.43 s, *SD* = 17.77 s) and neutral conditions (*M* = 95.89 s, *SD* = 89.09 s). Levene's test for homogeneity of variance was significant, *F* = 4.84, *p* = .044, so equal variances were not assumed, *t*(8.808) = -2.380, *p* = .042 (see Figure 4), suggesting that dogs helping behaviors may be dependent on humans' emotional states.

**Stress Behaviors**

For the prosocial helping task, which lasted up to five minutes, the total stress scores ranged from 0 to 280 behaviors (*M* = 81.43, *SD* = 82.84 behaviors). These scores were scaled to take into account differences in trial length and the length of time each dog was visible in the videos used to code behaviors (*M* = 0.46, *SD* = .31 behaviors/s). During the 10 minute baseline heart rate recording, there were anywhere from 0 to 498 behaviors (*M* =180.89, *SD* = 157.96 behaviors). These scores were also scaled based on visibility in the video (*M* = .38, *SD* = .31

behaviors/s). As expected, stress behaviors per second between baseline and testing were correlated, *r*(34) = .580, *p* < .001, where dogs that were more stressed during baseline were also more stressed during the prosocial task (see Figure 5).

Latency to opening was highly correlated with stress behaviors per second during the prosocial task, *r*(35) = .455, *p* = .006, where dogs with fewer stress behaviors per second opened more quickly than dogs that showed higher stress levels. To investigate this further, this correlation was run separately for each condition. There was no relationship between opening rate and stress in dogs in the neutral condition, *r*(17) = .164, *p* = .530. In contrast, opening speed and stress were highly correlated in dogs in the distress condition, where dogs that were more stressed took longer to (or never actually did) open the door, *r*(17) = .724, *p* = .001 (see Figure 6). This may indicate that different mechanisms underlie the relationship between stress and opening behaviors in each condition.

A three-way ANOVA was used to compare stress behaviors per second across conditions (neutral vs. distress), time periods (baseline vs. prosocial task), and whether the dog opened the door. There was no significant difference in stress behaviors per second between baseline and the prosocial task, *F*(1, 30) = 1.95, *p* = .173. There was a marginally significant main effect of opening on stress behaviors per second, *F*(1, 30) = 3.10, *p* = .088, where dogs that opened were on average over both time periods slightly less stressed (*M* = .340, *SD* = .264 behaviors/s) than dogs that did not open (*M* = .493, *SD* = .269 behaviors/s; see Figure 7). There was also a significant interaction between time period and opening, *F*(1, 30) = 6.55, *p* = .016. Dogs that opened showed very little difference in stress between baseline (*M* = .31, *SD* = .26 behaviors/s) and the prosocial task (*M* = .37, *SD* = .33 behaviors/s), while dogs that did not open were significantly less stressed during baseline (*M* = .39, *SD* = .32 behaviors/s) than they were during the prosocial task (*M* = .60, *SD* = .30 behaviors/s; see Figure 8). There was also a marginally significant interaction between time period and condition, *F*(1, 30) = 2.62, *p* = .116. Dogs in the distress condition showed less stress during baseline (*M* = .316, *SD* = .243 behaviors/s) than during the prosocial task (*M* = .500, *SD* = .313 behaviors/s), while dogs in the neutral condition had more similar stress levels during baseline (*M* = .440, *SD* = .373 behaviors/s) and the prosocial task (*M* = .422, *SD* = .318 behaviors/s; see Figure 9). Lastly, there was a marginally significant interaction between condition and opening, *F*(1, 30) = 3.10, *p* = .088. Dogs in the distress condition that opened (*M* = .224, *SD* = .134 behaviors/s) were less stressed across both time periods than dogs in this condition that did not open (*M* = .543, *SD* = .191 behaviors/s); dogs in the neutral condition had similar stress behaviors regardless of whether they opened (*M* = .431, *SD* = .310 behaviors/s) or not (*M* = .431, *SD* = .347 behaviors/s; see Figure 10).

Interestingly, there was no interaction between time period, condition, and opening, *F*(1, 30) = .031, *p* = .862. To illustrate this, the change in stress behaviors between the prosocial task and baseline was calculated, where a positive value indicates that the dog was more stressed during the prosocial task than baseline. Regardless of condition, dogs that did not open became more stressed from baseline to the prosocial task, while dogs that opened showed either no change or in fact a decrease in behaviors from baseline to the prosocial task (see Figure 11).

## Heart Rate Variability

The average pNN50 across both trial phases, during baseline recording and testing, was relatively low (*M* = 36.75, *SD* = 18.90%) for pet dogs compared to in-home baselines (Craig, Meyers-Manor, Anders, Sütterlin, & Miller, 2017). Neither pNN50 during baseline or during the prosocial task correlated with latency to opening, *p*s > .05. Baseline pNN50 correlated with their pNN50 during the prosocial task, *r*(34) = .428, *p* = .016. When dogs that opened were analyzed separately from dogs that did not open, an interesting trend emerged. Baseline pNN50 correlated with prosocial task pNN50 in dogs that opened, *r*(12) = .656, *p* = .020, but not in dogs that did not open, *r*(18) = .284, *p* = .254 (see Figure 12). Dogs that opened the door had baseline HRV that was predictive of their HRV during the prosocial task, whereas dogs that did not open showed no relationship between their prosocial task and baseline HRV.

A three-way ANOVA was used to compare pNN50 variation by condition (neutral vs. distressed), time period (baseline vs. prosocial task), and whether a dog opened the door. The pattern of results found with HRV contrasts with those found during analyses of stress behaviors. There was a significant difference in pNN50 from the baseline phase to prosocial task phase, *F*(1, 35) = 5.68, *p* = .025, where there was lower HRV (less variability) during the prosocial task (*M* = 31.43, *SD* = 16.92%) than during baseline (*M* = 41.73, *SD* = 19.54%; see Figure 13). If HRV is a valid measure of stress behaviors, this would indicate that dogs were more stressed during the prosocial helping task than they were during the baseline period. No other comparisons showed significant variation, *p*s > .05.

## Heart Rate Variability and Stress Behaviors

Pearson correlations were calculated to compare stress score over time with measures of HRV. This allows for evaluation of HRV as a valid measure of stress in dogs in this experiment. Baseline pNN50 was negatively correlated with baseline stress behaviors per second, with more stress corresponding to lower HRV, *r*(33) = -.397, *p* = .022 (see Figure 14). In contrast, there was no relationship between stress behaviors per second and pNN50 during the prosocial task, *r*(31) = -.219, *p* = .236. Looking only at dogs that did not open, since dogs that opened the door inherently had shorter recording lengths which might influence the validity of their HRV measures, pNN50 was negatively correlated with stress during the prosocial task, *r*(18) = -.619, *p*

= .006 (see Figure 15). Taken together, these results provide some support for the assertion that HRV in dogs can serve as a measure of physiological response to a stressful situation.

Correlations between HRV and stress behaviors were then run separately by opening and condition to better understand the physiological patterns underlying behavior in these distinct situations. Dogs in the distressed condition that did not open had no relationship between their baseline and prosocial task pNN50, *r*(10) = .079, *p* = .829. There was also no relationship between baseline stress and baseline pNN50, *r*(10) = -.122, *p* = .737. During the prosocial task, however, stress behaviors per second was highly correlated with pNN50, *r*(10) = -.754, *p* = .012, where dogs that were more stressed had lower HRV.

Dogs in the distressed condition that opened showed interesting results, although their small sample size (n = 4) makes it difficult to make claims about these trends. pNN50 appears to be correlated between baseline and the prosocial task, although this correlation was not significant, *r*(4) = .600, *p* = .400. Stress score during the prosocial task was insignificantly negatively correlated with pNN50, *r*(4) = -.558, *p* = .442, where dogs with lower HRV tended to have higher stress scores.

With dogs in the neutral condition that did not open, there was a significant positive correlation in pNN50 between baseline and the prosocial task, *r*(8) = .780, *p* = .022. There was also a significant negative correlation between stress behaviors per second and pNN50 during baseline, *r*(8) = -.835, *p* = .010, where, again, dogs with higher stress behaviors showed lower HRV. There was a similarly negative correlation between stress behaviors and pNN50 during the prosocial task, although it was not significant, *r*(8) = -.575, *p* = .136.

Finally, dogs in the neutral condition that opened also showed the correlation between baseline and prosocial task pNN50, although it was marginally significant, *r*(8) = .704, *p* = .051.

Interestingly, there was no correlation between stress behaviors and pNN50 during baseline, *r*(8) = -.129, *p* = .761, and in fact it trended in the opposite direction during the prosocial task, although this was not significant, *r*(8) = .342, *p* = .407. Clearly, these results illustrate that more research must be done to understand the complexity of HRV as a measure of stress in dogs.

### Impossible Task

On average, dogs spent more time (*M* = 2.92, *SD* = 3.85 s) gazing at the owner than at the stranger (*M* = 1.21, *SD* = 1.16 s), but even more time (*M* = 20.44, *SD* = 11.40 s) engaged in task-oriented behaviors. This corresponds to an average of about two thirds of total person-oriented gaze directed at the owner (*M* = 60.82, *SD* = 34.35%) and one third at the stranger (*M* = 36.32, *SD* = 33.28%). There was no difference in percentage of gaze toward the owner between the neutral and distress conditions when all dogs were considered, *t*(33) = .86, *p* = .398. There was also no difference in owner-directed gaze between dogs that opened and did not open, *t*(32) = -.72, *p* = .479. The amount of time that a dog spent gazing at their owner during the impossible task was not significantly correlated with their latency to opening the door during the prosocial task, *r*(34) = -.246, *p* = .161.

Because the difference in opening behaviors may be indicative of different emotional and bonding behaviors overall, dogs that opened were analyzed separately from dogs that did not open with respect to their gaze behaviors. There was a marginally-significant difference in percentage of gaze towards the owner between dogs in the neutral and distress conditions for openers. Levene's test for homogeneity of variance was significant, *F* = 4.91, *p* = .044, so equal variances were not assumed, *t*(12.098) = 2.02, *p* = .067, where dogs in the distress condition gazed at the owner more (*M* = 81.89, *SD* = 18.71%) than dogs in the neutral condition (*M* = 52.32, *SD* = 38.57%; see Figure 16). In contrast, there was no difference in percent gaze towards owner between the neutral and distress conditions in dogs that did not open, *t*(16) = -.29, *p* = .773. Further, there was a marginally-significant difference between openers (*M* = 81.89, *SD* = 18.71%) and non-openers (*M* = 54.33, *SD* = 32.31%) in percent gaze duration towards the owner among distressed dogs, *t*(15) = -2.02, *p* = .062 (see Figure 17). No such difference was seen in the neutral condition, *t*(15) = .37, *p* = .720.When only dogs that opened the door were included, there was a significant negative correlation between latency to opening and gaze at the owner, where dogs that opened more quickly gazed at the owner for more of the impossible task than dogs that opened more slowly, *r*(16) = -.502, *p* = .047 (see Figure 18).

## Discussion

First and foremost, this experiment found evidence that dogs will provide prosocial help towards humans: almost half of the dogs opened the door. Door opening seems to be a prosocial behavior that dogs will consistently perform. Bräuer et al. (2013) demonstrated that a dog could help a person retrieve a key from behind a door by pressing a button on the floor. They did so more often when the human more clearly communicated their desire to get into the room (Bräuer et al., 2013). The dog had previously opened the door to receive a food reward, and it was a relatively easy behavioral response for the dog to make. However, training could not explain all of their helping behavior, as they did not open the door as often when there was no food reward and the human was not clearly indicating that they wanted to enter the room. Therefore, it appears that dogs will open a door, either to get to a person or to allow the person to enter a room, and that this opening is dependent to some extent on their understanding of a benefit to the human from it being opened.

Analyses beyond comparisons of opening frequency yield more interesting implications about dogs' empathetic and prosocial behaviors. The speed with which dogs opened indicates that they were sensitive to their owners' emotional states. That dogs were faster to open the door in the distress condition than in the neutral condition indicates that human distress conferred urgency to the dog's actions or commanded their attention, leading them to open more quickly if they opened at all. Behavioral stress measures indicate that the experimental manipulation was effective, as dogs in the distress condition were more stressed during testing than during baseline, while dogs in the neutral condition were equally stressed during either time period. This pattern of results is consistent with previous research on empathetic responding in dogs. Custance and Mayer (2012) compared dogs' responses to crying and humming people, in terms of approaches and which human they were attending to. They found that dogs evaluate the emotions of humans and that, regardless of familiarity, they approach a crying person more often than a humming person, and appeared concerned when they did so (Custance & Mayer, 2012). This study furthered the investigation of empathy as a motivator of prosocial helping in dogs because it added a barrier between the dog and human, meaning that in order to approach their owner, the dog had to overcome a physical impediment. The approach behavior had to be even more strongly motivated in order for the dogs to overcome the physical barrier, and as such the response was not just an empathetic emotional response but instead closer to a behavioral helping response. It appears that the motivation to open the door was stronger when the human acted distressed than when they simply hummed, as indicated by the faster speed with which dogs pushed through the door in the former situation.

These results also raise the possibility that opening in the prosocial helping task was differentially motivated depending on condition. The difference in stress response between openers and non-openers in the distress and neutral conditions may support the claim that dogs differentially modify their behaviors based on humans emotional states, and that an empathetic capacity can lead to prosocial helping. Dogs in the distress condition that opened were lower stress than dogs that did not open. This is due to the difference in their stress levels during the prosocial task, not baseline. In fact, openers had similar stress levels during the prosocial task and baseline, whereas non-openers were significantly more stressed during the prosocial task than baseline. This pattern may be evidence of a similar emotional regulation mechanism affecting canine helping behaviors as has been seen in children, where help can only be provided by individuals who can sufficiently suppress their own experience of personal distress (Eisenberg et al., 1996; Fabes et al., 1993). It appears that in this experiment the helpers in the distressed condition were dogs that were able to suppress their personal distress. Non-helpers seem to have been overwhelmed by it, which prevented them from making a helping response. Also within distressed dogs, latency to opening correlated with stress behaviors, where dogs that were less stressed opened the door more quickly than dogs that were more stressed. Altogether, these results indicate that helpful dogs were more efficient helpers if they were better able to regulate their emotional response, while unhelpful dogs were less able to regulate their personal emotional response to the distressing situation. Consistent with previous research, it appears that a deficit in emotional regulation was what prevented the non-openers from acting empathetically (Eisenberg et al., 1996).

In the neutral condition, a dog’s stress response did not appear to account for their opening behaviors. Dogs were not more stressed during the prosocial task than they were during baseline, and there was no difference in stress level between openers and non-openers. It is possible that there were two types of openers in the neutral condition. High stress openers may have opened because they were stressed due to the novelty of the situation or separation anxiety and opened regardless of their human’s emotional state. For a stressed dog, a calm, familiar human could serve as an external source of comfort and emotional regulation (Kuhne et al., 2014). Low stress openers may have opened due to curiosity or a desire to interact with their owner that was not driven by an evaluation of their owner's distress. Helpers in empathetic situations are likely to be higher in emotional regulation and show fewer personal distress behaviors (Eisenberg & Fabes, 1990; Eisenberg et al., 1996; Fabes et al., 1993), so the lack of difference in emotionality between openers and non-openers in the neutral condition supports that openers were not motivated by empathy. For both the curious and anxious dogs, egoism rather than empathy is the likely driver of opening in this condition.

There may be an optimal amount of vicarious emotional response that allows for empathetic helping. This follows from longstanding research on the magnitude of a stress response for optimal performance, the Yerkes-Dodson law, which states that performance is best at a moderate level of emotional arousal and decreases with an increase or decrease from this level of stress (Yerkes & Dodson, 1908). This law clearly applies to an individual's empathetic help-giving capacity. To a point, increases in distress lead to increases in empathetic responding, such as when humans are more likely to provide help (especially to familiar people) when a situation is perceived as more serious (Cialdini et al., 1997). On the other hand, individuals with prohibitively high emotional responses to another's distress are more likely to egoistically seek a reduction of their own distress than to provide help (Eisenberg & Fabes, 1990; Fabes et al., 1993). This can be due to a combination of an individual's predisposition to stressful reactions as well and the severity of the emotional situation as both contribute to an overwhelming sense of personal distress. Therefore, when the amount of distress is kept constant across individuals, a differential ability to regulate one's emotions becomes incredibly important in determining their empathetic capacity (Eisenberg et al., 1996). These mechanisms governing the relationship between emotional regulation and empathetic responding appear to be in play when dogs opened in the distress condition, but not in the neutral condition.

The trends in gaze direction during the impossible task also appear to support the idea that opening in the distress condition was motivated by empathy, but not in the neutral condition. Gaze direction in this task is thought to be indicative of the closeness of the emotional bond between dogs and humans, where dogs gaze longer at individuals to whom they are more closely bonded (D’Aniello et al., 2015; D’Aniello & Scandurra, 2016). Empathy is typically strongest for individuals with whom one is most familiar (Cialdini et al., 1997), and it would be expected that dogs that are more strongly bonded to their humans would be better at discerning their emotional state. This would then lead to a heightened likelihood of empathetic behaviors towards them. Among dogs that opened, dogs in the distress condition for the prosocial task gazed significantly more at their owner during the impossible task than dogs in the neutral condition. This supports the idea that dogs in the distress condition may have opened because they were more closely bonded with their owner, and therefore more likely to be attentive to their owner’s emotional state, whereas this did not appear to be the case with openers in the neutral condition. Further, dogs in the distress condition that opened were more attentive to their owners during the impossible task than dogs in the distress condition that did not open. The ability to suppress one’s own distress and attend to the emotional state of another is a hallmark of the empathetic response (Eisenberg et al., 1996; Fabes et al., 1993), and appears to be the differentiating factor between openers and non-openers in the distress condition, since they differ with respect to their owner-directed attention. By this logic, the lack of difference in owner-directed gaze during the impossible task between openers and non-openers in the neutral condition further supports the theory that the dogs that opened in the neutral condition were not motivated to do so by empathetic evaluations of their owners' emotional states.

The interpretation of HRV as it relates to emotional regulation and empathy in this study is less clear-cut. The likelihood of opening was not predicted by HRV. This is surprising, as previous research on the relationship between empathy and HRV in humans found that children with higher HRV were more likely to show empathetic behaviors because they have better emotional regulation (Fabes et al., 1993). One would expect that dogs that opened would have shown higher baseline HRV, as this would serve as a proxy measurement for trait emotional regulation capacity, but this result was not obtained. However, baseline HRV was related to baseline stress measurements. As expected, dogs with higher HRV showed fewer stress behaviors (Katayama et al., 2016). Also, taken with the increase in behavioral measures of stress from baseline to testing in dogs that did not open the door, the decrease in HRV from baseline to testing is consistent with the idea that HRV decreases with stress (Katayama et al., 2016). The relationship between baseline and prosocial task HRV highlights the importance of an individual's trait emotional regulation capacity, where individuals with high HRV that are lower stress in situations of neutral affect are better able to cope in emotionally-stimulating situations (Fabes et al., 1993).

The correlation in HRV between baseline and the prosocial helping task in dogs in the neutral condition (and not in dogs in the distress condition) may reflect a difference in the relative importance of trait and state HRV. In dogs in the neutral condition, the amount of HRV that a dog displayed during baseline predicted their HRV during the prosocial task; this means that their individual differences in HRV were evident and consistent across both time periods. In the distress condition, on the other hand, there was no relationship between baseline and prosocial task HRV. During baseline, it seems that the range of HRV values was reflective of their individual differences in emotional regulation. During the prosocial helping task, in contrast, dogs' HRV reflected more strongly the influence of the stressfulness of the experimental situation. Because of the shift from trait to state dominance, the individual differences were overwhelmed.

The lack of relationship between baseline HRV and opening behaviors is unexpected. The low HRV appears to indicate that all dogs were stressed during the prosocial task, despite the variation in behavioral indices of stress (Craig et al., 2017; Fabes et al., 1993; Katayama et al., 2016; Kuhne et al., 2014). The relatively high overall arousal was likely due to a combination of separation distress, the novelty of the situation, and the unfamiliarity of the testing arena. Further studies should make use of habituation, allowing dogs to become accustomed to the arena prior to the prosocial helping task in order to decrease overall distress and anxiety, as has been done in comparable studies in rats (Ben-Ami Bartal et al., 2011; Silberberg et al., 2014). The importance of decreasing distress is further supported by the lack of overall difference in stress behaviors between the distress and neutral conditions. It is perplexing that HRV decreased from baseline to testing while stress behaviors did not comparably increase across these periods, given that stress and HRV were correlated during baseline as well as during testing among non-openers. Further research will be required to better understand the relationship between stress and HRV, and under what circumstances HRV is predictive of behavioral manifestations of stress.

The HRV results in this study must be interpreted with caution due to constraints on their reliability under certain recording lengths. In fact, both the stress and HRV measures utilized in this study are influenced by recording length, and openers naturally had shorter recordings than non-openers. In particular, the measure used to evaluate HRV in this experiment, pNN50, is not considered reliable for samples under 20 s (Sütterlin, personal communication). Because the dogs in the distress condition who opened did so on average within about 20 s, their heart rate samples for the trial period should be interpreted with caution. Further research must be done to determine whether HRV is a good indicator of emotional regulation in dogs, and whether it relates to empathetic helping as has been seen in humans (Eisenberg & Fabes, 1990; Fabes et al., 1993).

The presence of empathetic helping behaviors differs from other studies that found no evidence of prosocial behaviors towards humans in a help-requiring situation (Macpherson & Roberts, 2006; Quervel-Chaumette et al., 2016). The wide variation in the methods of these experiments may be responsible for the discrepancies between their results. Macpherson and Roberts (2006) had a human feign being in danger, and helping by the dog was operationalized as an attempt to get another human's attention and elicit help. However, that human was not reacting to the situation, and research on the bystander effect in humans would indicate that the presence of uninterested witnesses reduces one's concern about an emergency situation (Latané & Darley, 1968). Therefore, it is possible that in this situation the dogs did not attempt to elicit help from humans because they could tell that the humans were unaffected by the situation and used that information to infer something about the situation's severity.

Quervel-Chaumette et al. (2016) operationalized prosocial helping as the pulling of a lever to put food into an adjacent compartment, which either contained a familiar human or a dog. Dogs pulled the lever for a fellow dog, not for a human, leading to the conclusion that dogs would not provide prosocial help toward humans (Quervel-Chaumette et al., 2016). However, it may be that a dog would not evaluate their owner to be in need of help obtaining food, since that is not a circumstance that domestic dogs typically encounter in a modern home. Further, the human was not allowed to communicate with their dog during the experiment, and it appears that the communication of intent is important for dogs to show helping responses (Bräuer et al., 2013). To attempt to rectify the difficulty in the interpretation of such results, the method of the present study required dogs to attempt to overcome a physical barrier in order to reach a person in distress. Additionally, there were no unreactive humans in the experimental chamber. These results may underscore the importance of using definitions of empathy that make sense in the context of a domestic dog's normal behavioral repertoire.

These results continue the conversation about the validity of the trapped-other paradigm as a measure of empathetic helping (Ben-Ami Bartal et al., 2011; Silberberg et al., 2014). Because human confederates are able to be instructed to adopt a particular valence of their emotional display, this experiment had the potential to illuminate whether the opening response is motivated by a desire to provide empathetic help or to receive social contact. The lack of difference in opening rate between conditions appears to support the latter claim (Silberberg et al., 2014), but the significant difference in latency as well as the behavioral measures of stress and emotional bonding between openers and non-openers in the distress condition all support the former (Ben-Ami Bartal et al., 2011). It also appears that dogs were not opening solely out of an egoistic desire for comfort, as the dogs that opened the door did not show higher distress as quantified by either HRV or behavioral stress.

These results must be interpreted with caution. While openers were less stressed than non-openers, the emotional experiences of the dogs as measured by HRV did not appear to significantly vary with opening. If helping had been motivated by a desire for social contact, dogs that showed lower baseline HRV would have opened more often because their need for external comfort in order to regulate their unpleasant emotional state would have been improved by contact with their owner (Silberberg et al., 2014). This aligns more closely with the pattern seen in the neutral condition, where there was no difference in stress between openers and non-openers, than it does with the distress condition, where openers were less stressed than non-openers. A claim of empathetic motivation, on the other hand, would have been best supported by higher baseline HRV in dogs who opened and who did so more quickly (Eisenburg & Fabes, 1990). Importantly, that was the trend seen in the behavioral stress measurements, particularly among dogs in the distress condition. It is unlikely that the HRV simply did not reflect dogs' emotional states, though, since previous literature has found a strong relationship between emotional state and HRV in dogs (Katayama et al., 2016; Kuhne et al., 2014).

There are limitations to the claims that can be made about empathy and prosocial helping in dogs from the present study. The size of the sample of this experiment may have contributed to a lack of significance in some of the comparisons. Namely, there were a few strong correlations that did not reach significance, at least in part because some of the groups were too small (such as n = 4 for openers in the distress condition with HRV recordings). A larger sample size would have helped to elucidate whether these correlations were relevant or spurious. The ambiguity of some of the other results highlights the importance of taking care when designing paradigms to evaluate animals' capacity for empathy. Future paradigms should be carefully constructed to decrease stress, such that dogs are able to be less physiologically aroused. One potential approach that could decrease overall physiological arousal would be to run the experiment in the dog's home, where they would be significantly less distressed due to the familiarity of their surroundings. Previous research that found evidence for empathy in dogs took place in the home (e.g., Custance & Mayer, 2012), and perhaps the stress of unfamiliar surroundings makes it more difficult for dogs to evaluate humans' emotions, suppress their owner distress, and respond prosocially (e.g., Macpherson & Roberts, 2006; Quervel-Chaumette et al., 2016). Running this experiment in the dog's home would allow for a wider range of emotional responses and a decrease in overall anxiety, thereby making room for HRV to vary with the owner's emotional condition.

Another concern is that, during this study, owners were instructed to not make direct eye contact with the dog (opting to look slightly above eye-level instead) to prevent different amounts of eye contact between conditions (as crying participants would be more likely to close their eyes and avert their gaze than humming participants). This may have confused the dogs as to whether or not their owner was attempting to communicate with them. Studies on prosocial helping must be particularly careful because dogs appear to take intentionality into account when deciding whether to provide help (Bräuer et al., 2013; Quervel-Chaumette et al., 2016). Future investigations into empathetic responses should take care not to restrict what may be important signals in human-dog communication.

Additionally, there was a great degree of variation in the crying and humming abilities of the human participants, where some were significantly more convincing than others. Although fake crying in previous experiments has been found to elicit empathetic responses (Custance & Mayer, 2012), the variability seen in the present sample may have had an influence on dogs' behavior. Future studies on helping with this paradigm could use pre-recorded audio clips of human vocalizations to standardize the emotional experience that each dog is exposed to during the trial, although this would likely require that the voice be unfamiliar for each dog. Another interesting test would be to compare helping toward recordings of human voices and canine vocalizations that are standardized with respect to emotionality. If dogs respond empathetically to crying humans, it is likely that they would respond similarly to distressed dogs, and the use of pre-recorded distressed or neutral dog vocalizations would allow for this comparison without sacrificing the comparison of responses in neutral and distressing situations.

The support for cross-species empathy and prosocial helping found in this experiment is consistent with previous research on non-human primates, who have shown empathy toward humans in certain tasks (Warneken & Tomasello, 2006). Whether or not dogs were motivated by empathy when they provided help to their owner in a help-requiring situation, they do appear to be capable of responding differently to humans based on their emotional states (Custance & Mayer, 2012). The extent of this empathetic response and under what conditions it can be elicited deserve further investigation, especially as it can improve understanding of the shared evolutionary history of humans and dogs. Future studies on empathy in animals will allow for a deeper understanding of this social cohesion mechanism, how it evolved, and how it can occur between individuals within one or between multiple species. This study contributes to the empathy conversation by providing support for empathetically-motivated prosocial helping in dogs. Dogs are most likely to provide help to a human in need if they are able to focus on the human’s need instead of their own personal distress.

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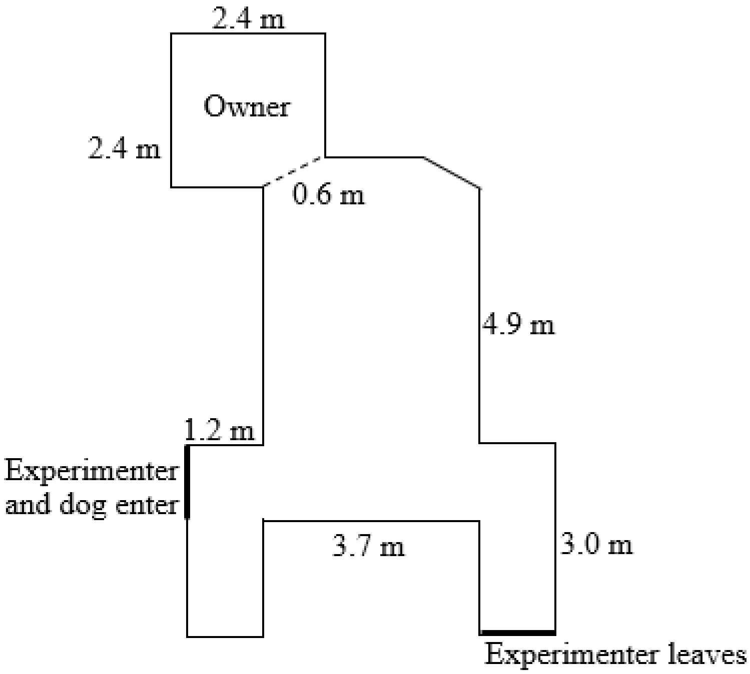

*Figure 1.* Schematic of the testing arena for the prosocial helping task.

*Figure 2.* Example view of dog through door from trapped owner's perspective during prosocial helping task.

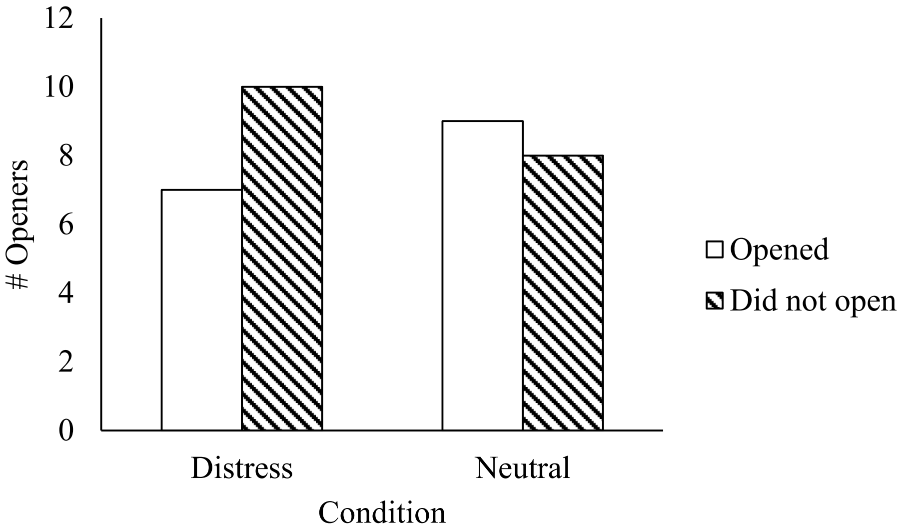

*Figure 3.* Number of dogs that opened by condition. There was no significant difference in frequency of opening between the distressed and neutral conditions.

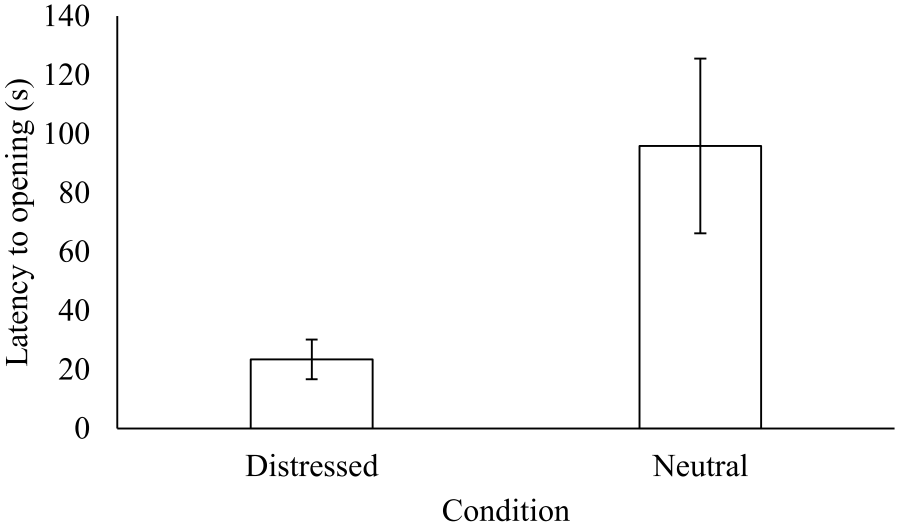

*Figure 4.* Latency to opening among dogs that opened the door by condition. Dogs opened significantly more quickly in the distress condition than in the neutral condition. Error bars represent standard error.

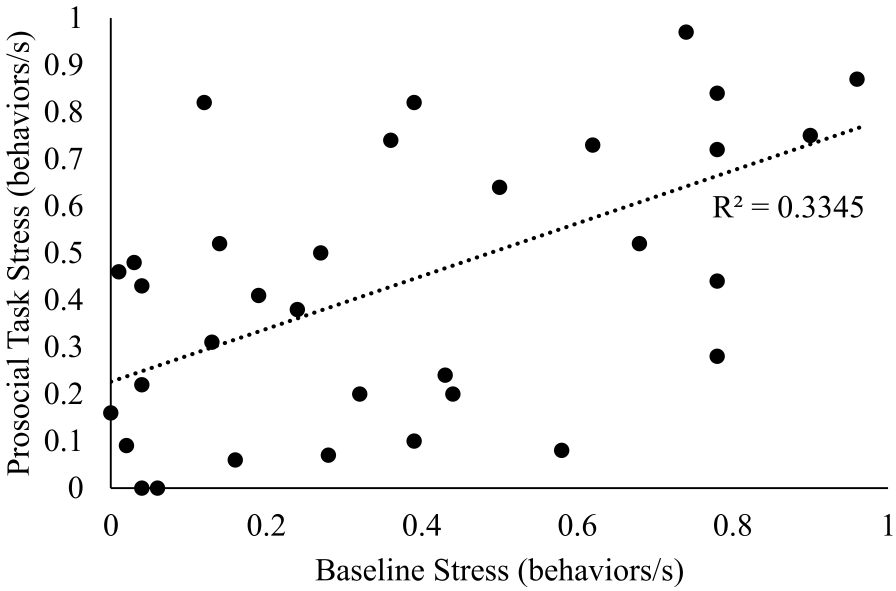

*Figure 5.* Stress behaviors per second during the prosocial task by stress behaviors per second during baseline. An increased stress level during baseline correlated with an increased stress level during the prosocial task.

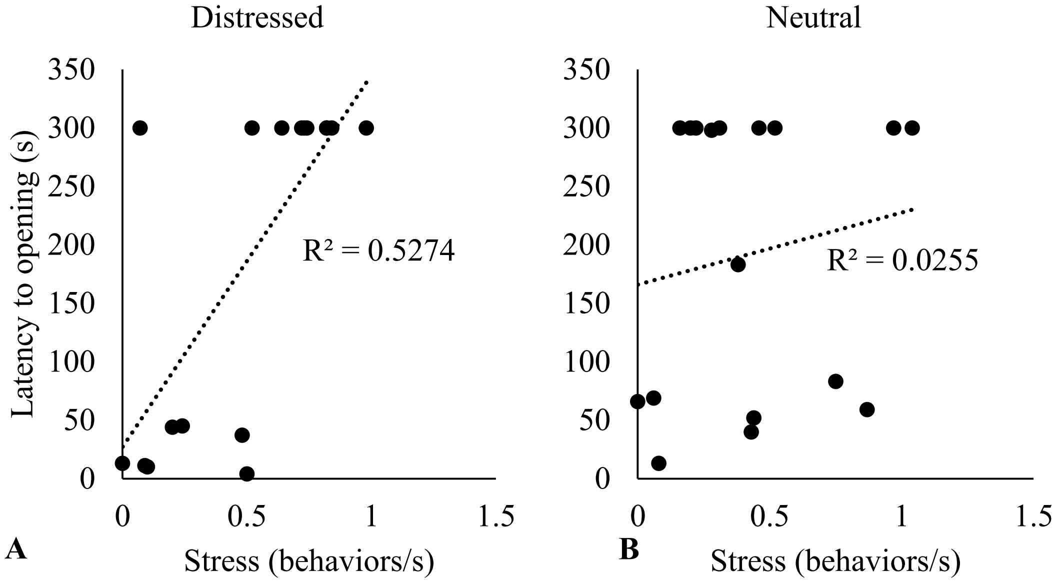

*Figure 6.* Latency to opening by stress behaviors per second. Dogs in the distressed condition (A) had stress behaviors that strongly correlated with their opening rate, whereas dogs in the neutral condition (B) had no relationship between their opening rate and stress score.

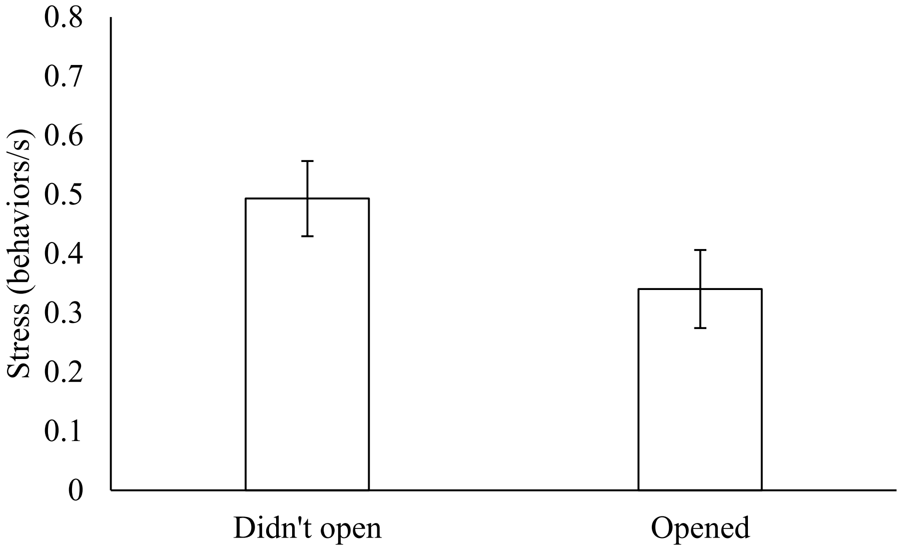

*Figure 7.* Stress behaviors per second by opening. Dogs that opened were less stressed overall than dogs that did not open. Error bars represent standard error.

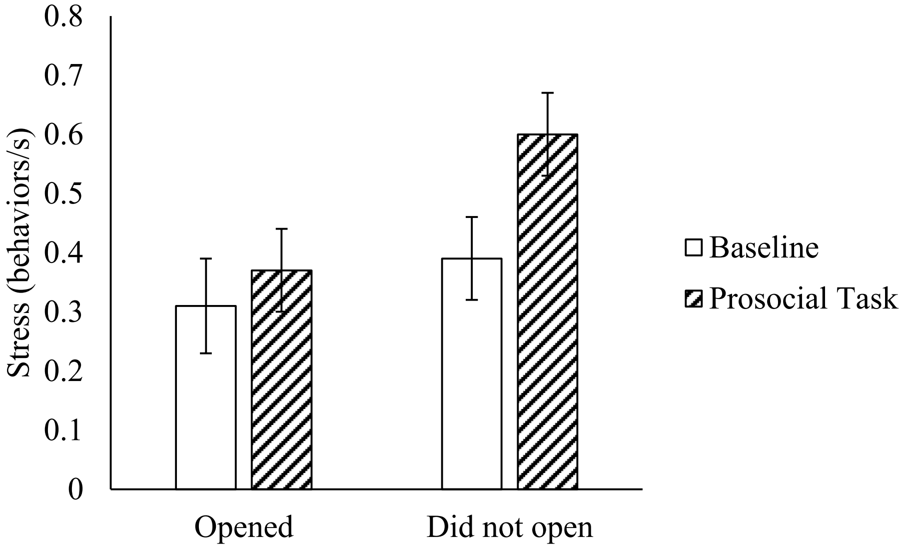

*Figure 8.* Stress behaviors per second by opening and time period. Dogs that opened did not show significantly different stress scores between baseline and the prosocial task, but dogs that did not open were significantly more stressed during the prosocial task than they were during baseline. Error bars represent standard error.

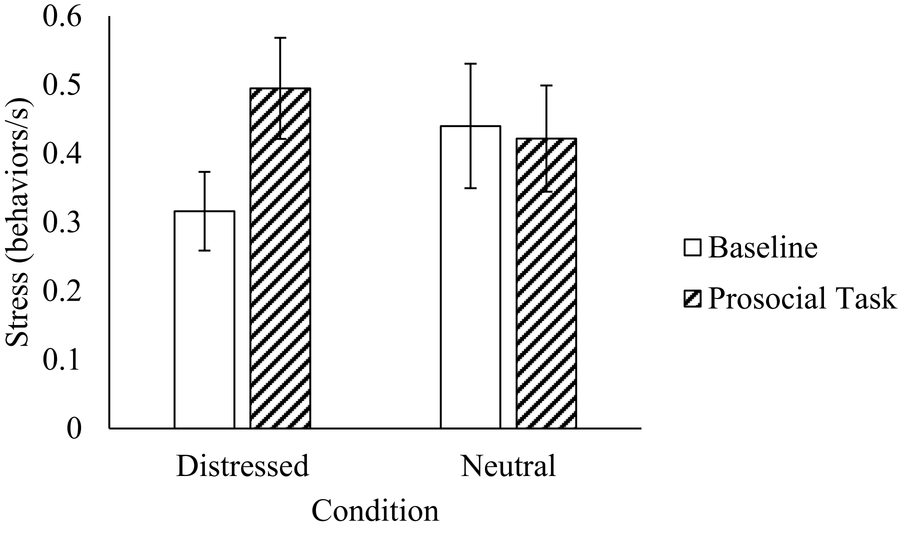

*Figure 9.* Stress behaviors per second by condition and time period. Dogs in the distressed condition showed more stress behaviors during the prosocial task than during baseline, whereas dogs in the neutral condition showed similar stress during both time periods. There was a marginally-significant interaction between condition and time period. Error bars represent standard error.

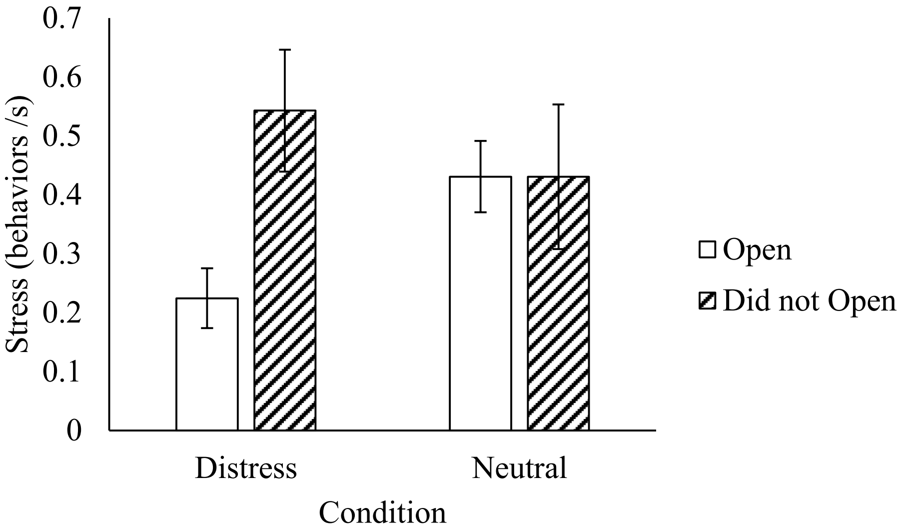

*Figure 10.* Stress behaviors per second by condition and opening. Dogs that opened in the distress condition were less stressed than dogs that did not open in the distress condition; dogs in the neutral condition were equally stressed whether or not they opened. Error bars represent standard error.

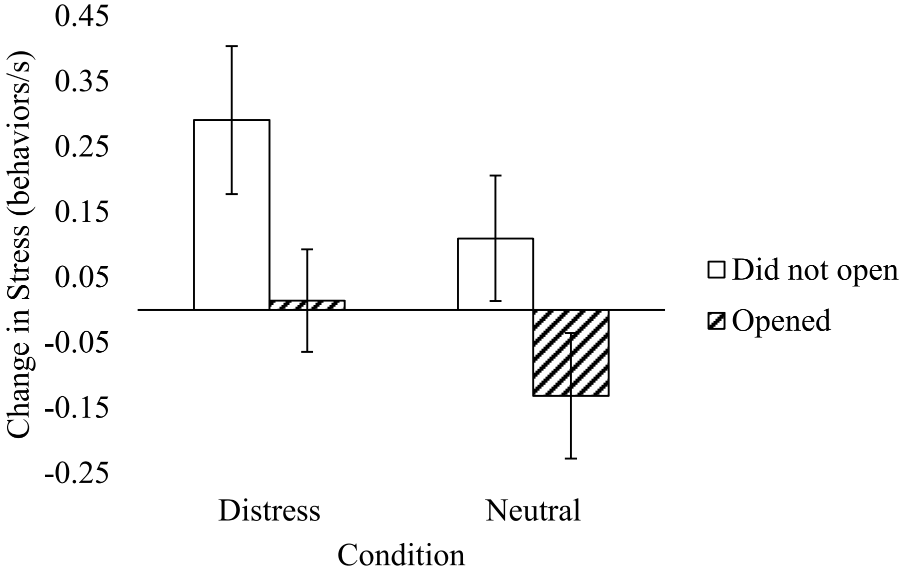

*Figure 11.* Change in stress behaviors per second (prosocial task minus baseline) by opening and condition. Regardless of condition, dogs showed an increase in stress behaviors from baseline to the prosocial task if they did not open, and showed no increase (or even a decrease) from baseline to the prosocial task if they opened. Error bars represent standard error.

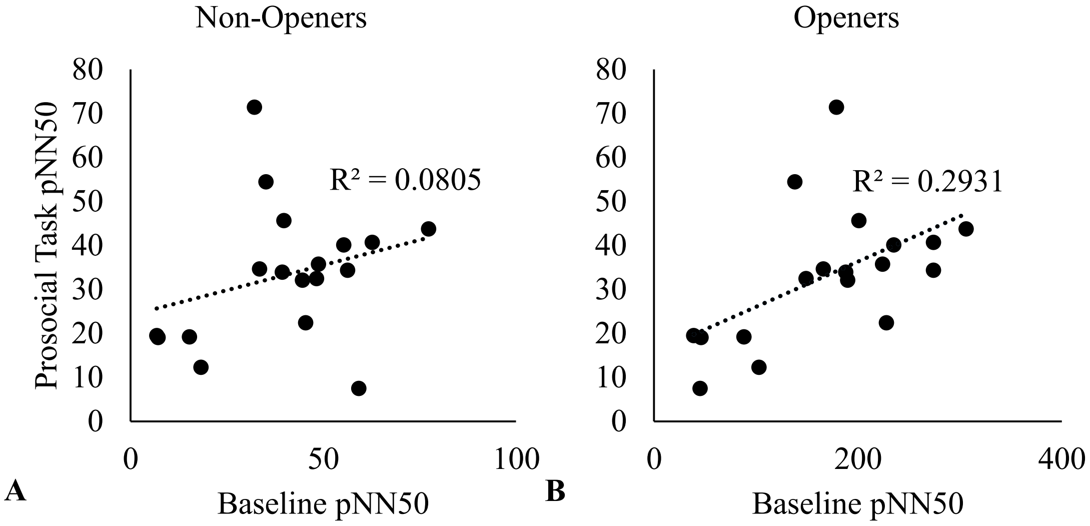

*Figure 12.* Prosocial task pNN50 by baseline pNN50. Among dogs that opened (B), pNN50 during baseline phase correlated with pNN50 during the prosocial task, while among dogs that did not open (A) it did not correlate.

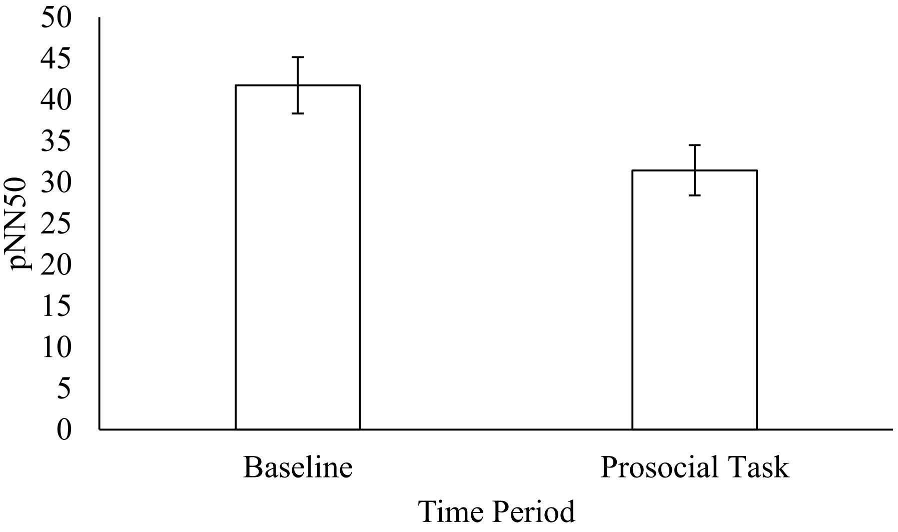

*Figure 13.* pNN50 by time period. Dogs showed significantly less HRV during the prosocial task than they did during baseline. Error bars represent standard error.

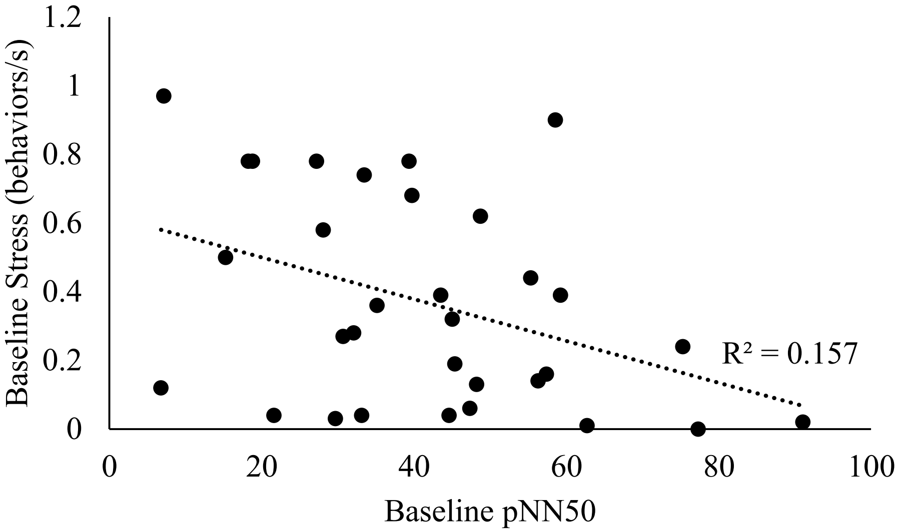

*Figure 14.* Baseline stress by baseline pNN50. Baseline pNN50 is negatively correlated with stress behaviors during baseline, where dogs with lower HRV showed more stress behaviors.

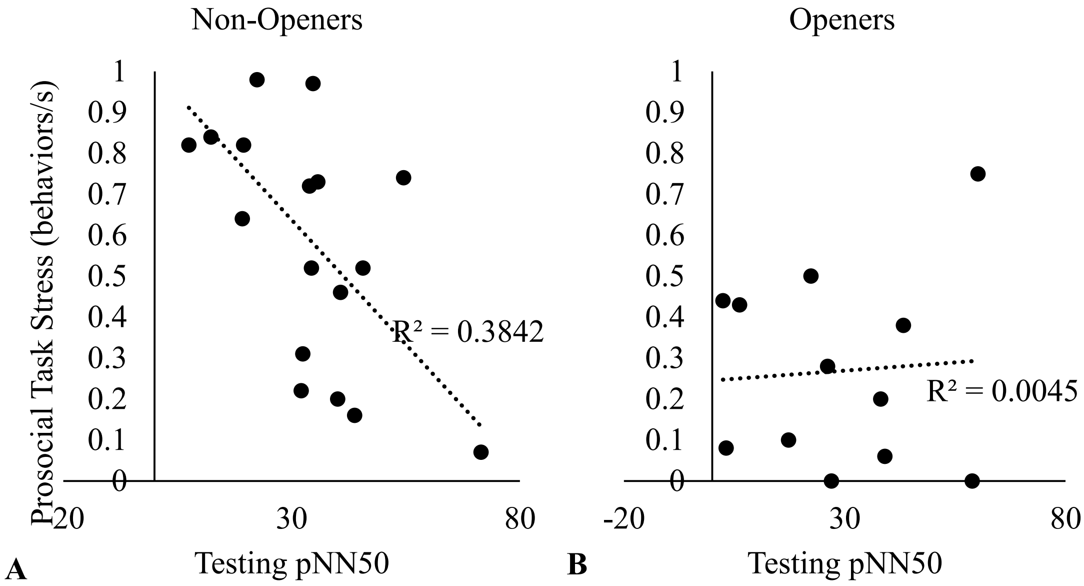

*Figure 15*. Prosocial task stress behaviors by testing pNN50. Among dogs that did not open (A), pNN50 during the prosocial trial is negatively correlated with behavioral stress score. This correlation was not seen among dogs that opened (B), possibly due to a decrease in the validity of HRV measures in shorter recording periods.

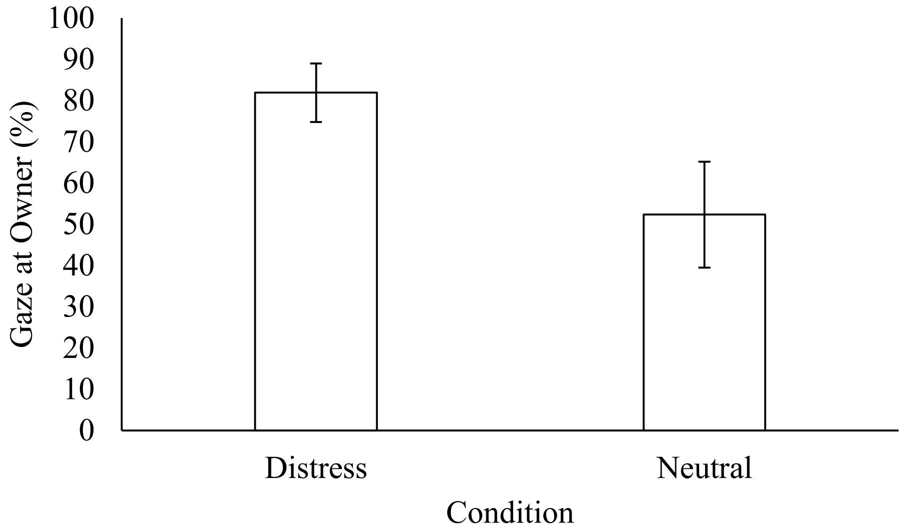

*Figure 16.* Percentage gaze duration toward owner during the impossible task by condition during the prosocial helping task among dogs that opened the door. Dogs that opened the door during the prosocial helping task while in the distress condition gazed at their owner significantly more during the subsequent impossible task than dogs that had been in the neutral condition. Error bars represent standard error.

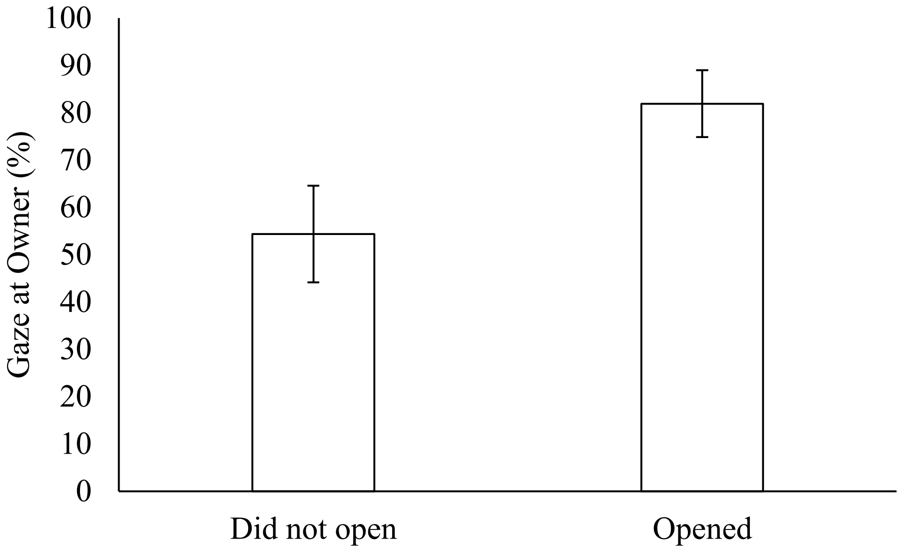

*Figure 17.* Within dogs in the distress condition, percentage gaze at owner during the impossible task by whether the dog opened the door during the prosocial task. Dogs that opened the door gazed more at their owner during the prosocial task than dogs that did not open the door. Error bars represent standard error.

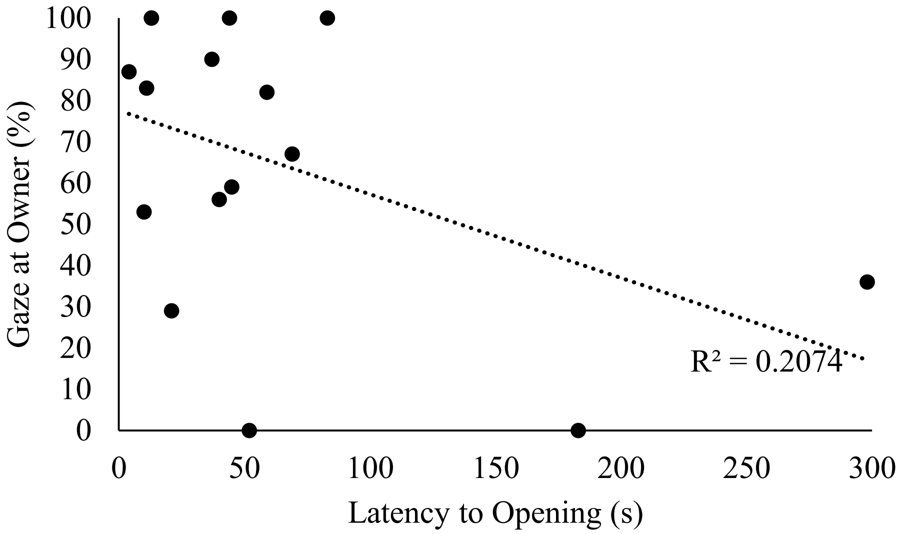

*Figure 18.* Percentage gaze at owner during impossible task by latency to opening during prosocial helping task. Dogs that opened more quickly during the prosocial task gazed at their owner for a larger proportion of time during the impossible task.