Variability in Human-Animal Interaction Research

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The field of Human-Animal Interaction (HAI) is plagued with mixed results. Some findings appear to indicate that interacting with a companion animal is beneficial for some aspect of human health and well-being, while other research outcomes are inconclusive or even indicate the opposite. The purpose of this paper is to take a closer look at this variability in research outcomes and to provide plausible explanations and potential remedies. Some of the reasons for mixed results are likely due to the wide variety of methodologies implemented, intermittent use of standardized measures and manualized protocols, variability in human and animal participants, and limited quantification of human-animal interactions or definitions of pet ownership. Variability in research outcomes is not unique to HAI and is, in fact, not uncommon in many more established fields such as psychology and medicine. However, the potential reasons for the variability may be linked to the unique nature of HAI in that, in its' simplest form, it involves two complex organisms, a human and an animal, interacting in dynamic ways. We argue that this complexity makes research in this field particularly challenging and requires a broad spectrum of theoretical and methodological considerations to improve rigor while ensuring the validity and reliability of conclusions drawn from study results.

Keywords: human-animal interaction (HAI), methodology, animal-assisted intervention (AAI), variability in outcomes, replication

INTRODUCTION

The idea that interacting with companion animals conveys health and well-being benefits to humans goes back for centuries. Empirical research on the impact of pets on people, however, dates to the 1980s (1). Among the most influential early investigations were studies reporting that pet owners had significantly lower rates of mortality following heart attacks (2) and that interacting with dogs produced decreases in blood pressure and levels of physiological stress (3). Over the last 20 years, research on the health and therapeutic implications of the human-animal bond, including animal-assisted interventions (AAI), has grown exponentially. Hundreds of papers on these topics are now published in academic journals each year, and centers devoted to the study of human-animal relationships have been established in North America, Europe, Asia, and Australia. In addition, nearly 50 educational institutions now offer undergraduate or graduate degrees in human-animal relationships (4).

In recent years, the notion that pet owners are healthier and happier than non-pet owners has gained popularity. A 2016 survey by the Human-Animal Bond Research Institute (HABRI) found that 71% of pet owners were aware of research showing that pets improve human mental

and physical health. Another HABRI survey found that 97% of family doctors who responded agreed there are health benefits of owning pets. There is a mismatch, however, between the results of empirical investigations and public perceptions of the positive effects of companion on human health and well-being (5). Some studies have found, for example, that pet owners have lower rates of mortality and obesity, higher self-esteem, are happier, and have decreased blood pressure and stress levels (6). Yet other studies have found no differences in these measures. Further, some researchers have reported that pet owners are more likely to suffer from disorders such as anxiety, insomnia, depression, obesity, ulcers, and panic attacks (6).

Research on pet ownership and loneliness exemplifies variations in results of studies on the impact of living with pets on well-being. Gilbey and Tani (7) reviewed 13 studies published between 1986 and 2014 comparing levels of loneliness in pet-owners and non-owners. Using standardized psychological instruments, five of the studies found that pet owners were less lonely, seven found no differences in the degree of loneliness in owners and non-owners, and one study reported mixed results (7). Further, only one of eight studies published between 2014 and 2020 found that pet owners were less lonely (8). Four of these studies reported no difference between the groups, and two produced mixed results. When the older and newer studies are combined, six reported beneficial associations between loneliness and pet ownership, while twelve found no association between pet-ownership and loneliness.

Outcomes from studies on the efficacy of animal-assisted intervention for improving human health and well-being have also not been uniformly positive, with similarly mixed results. For example, several studies have suggested that therapy dog visits may have beneficial physiological and psychological effects on hospitalized pediatric patients (9, 10). However, in one of the largest multi-site randomized controlled trials (RCT) on the effects of therapy dog visits on pediatric patients to date, researchers found that children in outpatient cancer treatment units who received 4 months of weekly therapy dog visits did not exhibit reduced stress, reduced anxiety, or improved quality of life compared to children randomized to treatment as usual (11). Reviews of the literature have pointed out significant threats to construct validity regarding the therapeutic value of the physical animal in AAI (12) as well as the potential for inflated false positives in findings (13) that may contribute to mixed findings in the field.

Variations in Research Results Are Common in Science

The high degree of variation found in the results of HAI research is also common in more established fields. Experimental psychology in particular has been plagued with conflicting findings. A 2015 article in Science reported the results of replication attempts of 100 studies published in three reputable psychology journals (14). Only 39% of the results of the original studies could be replicated. Indeed, the results of widely accepted findings in behavioral research have been called into question by inconsistent findings. These include the impact of nasal oxytocin

administration on interpersonal trust (15), changes in female mate preferences associated with ovulation (16), and the ego-depletion model of self-control (17).

Variability in outcomes is also common in clinical medicine. For example, a recent review of studies published in three leading medical journals found that standard treatments were based on the results of nearly 400 randomized controlled trials that failed to replicate (18). Among these were hormone therapies for menopause, breast cancer screening, knee surgery, and CPR techniques. A search of the phrase "variability in outcomes" in PubMed returned 195,828 hits, with 74,977 hits when restricted to the most recent 5-year period. The published manuscripts from these searches covered a wide range of topics such as the longitudinal course of posttraumatic stress disorder [PTSD; (19)], treatment of polycystic kidney disease (20), and recovery from arthroscopic anterior shoulder repair (21), to name but a few.

Concern for persistent variation in research results across science (the "replication crisis") was sparked by a 2005 paper by John Ioannidis titled, "Why Most Published Research Findings Are False." Ioannidis argued that inconsistent and false findings are particularly common in research areas that have several characteristics. These include small sample sizes, small effect sizes, "flexibility in designs, definitions, and outcomes" and, finally, fields that suddenly become "hot" (22). These problems are characteristic of many HAI research studies. Take, for example, a recent meta-analysis of research on the efficacy of animal-assisted psychotherapy for the treatment of trauma. The researchers found that seven of the nine clinical trials in the analysis were statistically underpowered; five of them had fewer than 17 subjects (23). A meta-analysis of eleven reports on the efficacy of prison-based dog programs found that most of the treatment effects in these studies were low [average $d = 0.15$; (24)]. Finally, HAI falls into Ioannides' "hot field" category. According to a Google Scholar search using the term "therapy dog," the annual number of published papers related to canine-assisted therapies jumped from 60 in 2010 to 237 in 2019.

VARIABILITY IN METHODS AND MEASUREMENT IN HAI RESEARCH

A specific consideration in explaining outcome variance in HAI research is that studies significantly vary in their methodological design and rigor. HAI researchers use a wide variety of designs to answer comparable questions in the field, ranging from case studies, single-subject research, and qualitative interviews to observational, cross-sectional, and longitudinal studies. While early studies in HAI were largely limited by a lack of control conditions and small sample sizes, more recent studies have substantially improved in their methodological rigor (25). Despite recent advances in methodology, systematic reviews of both animal-assisted intervention and pet ownership studies repeatedly state that is difficult to draw definitive conclusions from the data due methodological weaknesses across studies [e.g., (26, 27)].

An emerging number of studies using randomized clinical trial designs have shown promise in legitimizing the validity and

strength of evidence in the field. However, even conclusions from RCTs can be limited by a high risk of bias from inadequate concealment and blinding [e.g., (28)]. Even the most rigorous studies can also vary widely in their control or comparison conditions. For example, intervention studies may feature no control at all, an active control (e.g., interaction with toys or stuffed animals), or a no-treatment control (e.g., waitlist or withdrawal periods). With a variety of control and comparison conditions used in the field, this leads to both variability in outcomes as well as difficulty making cross-study comparisons. In a systematic review of eight RCTs evaluating the effects of AAI on psychosocial outcomes, several different comparison conditions were identified including treatment without an animal present, active comparisons with human visitation or quiet reading, and waitlist controls (29). The type of control condition used may have direct impacts in study results. For example, a moderator analysis conducted as part of a meta-analysis on the effects of AAI in medical settings found that studies with a social control condition (i.e., featuring human interaction but not animal interaction) had significantly smaller effect sizes than studies with a non-social control condition (30).

Additionally, there is widespread variability in measurement methods in HAI. Specifically, the use of standardized, validated measures to quantify outcomes has been inconsistent across HAI research (25). In a systematic review of 48 studies assessing AAI in the form of reading to therapy dogs among school-aged children, only 13 studies used standardized measures with established validity and reliability to measure outcomes (31). Rather, many studies incorporate subjective ratings, researcher-created measures, or modified existing measures which makes it difficult to compare findings across studies. Still, among studies that do incorporate standardized measures, the sheer number of measures available to quantify the constructs of interest to HAI research (i.e., mental health, social functioning, quality of life) has resulted in further variability in the literature. For example, a systematic review of 14 studies on the efficacy of AAI for children with autism found that no two studies used the same standardized assessment tool (32). This lack of replication of measurement across studies prevents the ability to make informed conclusions with meta-analytic methods, which is crucial for providing an evidence base for the field (33).

Standardized measures also vary in the appropriateness of content for the theoretical outcomes of HAI. For example, a popular scale of loneliness called the UCLA Loneliness Scale was recently evaluated for its appropriateness to quantify beneficial social effects of pet ownership (34). Both qualitative and quantitative evaluation suggested that only 6/20 items were likely sensitive to change following pet ownership or pet acquisition, concluding that despite its widespread use the scale lacks efficacy for quantifying the effect of pets on loneliness. Therefore, while the use of consistent measures across studies is important for replication purposes, measures must be chosen for their sensitivity to change following animal interaction.

VARIABILITY IN HUMAN PARTICIPANTS IN HAI RESEARCH

When quantifying the role that animals play in our lives, it is important to consider the heterogeneity in how humans may perceive, respond to, and interact with animals. Individual differences in demographic variables such as age, gender, and race/ethnicity may contribute significantly to outcome variance. For example, a meta-analysis of outcomes from AAT found that studies of young children had the most consistently positive outcomes, while other age groups exhibited more variability in outcomes (35). Not only may males and females have different hormonal responses to interaction with animals (36), but females have been found to report more positive behaviors and attitudes toward animals (37) and toward animal-assisted interventions in general (38). While these gender differences in attitudes and responses may not be unique to HAI, equal care should be taken to consider gender-specific effects in analyses as in other fields of research. Ethnicity, cultural, and religious differences may also contribute to attitudes and perceptions of animals (39, 40), However, neither demographic variables nor other potentially confounding variables such as marital status, sources of social support, and socioeconomic status are consistently controlled for in HAI studies (41). The omission of key explanatory variables in analyses can lead to invalid conclusions if unmeasured confounding variables are partially or fully explaining significant findings. For example, a recent systematic review of the impact that pets have on child and adolescent development found that 14 of 22 studies did not consider any confounding variables in analyses, leading authors to conclude that no firm conclusions can be drawn from the literature (42). In addition to controlling for these confounders, future large-scale research studies should also consider the extent to which demographic or contextual variables may mediate outcomes (43). Mediator and/or sub-group analyses may also aid in understanding for whom and under what conditions individuals benefit from HAI (5, 44).

In addition to demographic and environmental variables, human participants in HAI research often vary widely in their physical and mental health. As a key research question in this field is understanding how animal interaction may benefit individuals of sensitive populations, HAI research often includes a range of disabilities, disorders, and chronic conditions. Frequently, participants are selected for participation in research based on a single diagnosis (e.g., posttraumatic stress disorder, cerebral palsy, etc.). However, not only is there variation across studies in how and when this diagnosis was made, there can also be considerable phenotypic variation among individuals with the same condition (e.g., autism spectrum disorder, ASD). In a systematic review of 13 studies addressing the impact of AAI on social behaviors of children with ASD, nine different terms were used to describe participants' diagnosis and/or severity including autism spectrum disorder, autism, autistic disorder, moderate autism, early childhood autism, and atypical autism (45). Thus, it is difficult to compare results across these studies when participants' symptoms and behavioral profiles are markedly

different. Even in phenotypically similar disorders, there is also often participant variability in severity, progressiveness, and duration of the condition or disability. However, these factors are often not controlled for or considered in statistical analyses. For example, a systematic review of the effects of AAI on individuals with dementia found that only 13 of 32 studies controlled for the severity of dementia in their design or analysis (26). Disability severity and progressiveness can be important explanatory variables in psychosocial outcomes such as quality of life, however. In a 2006 study of the psychosocial effects of mobility service dogs for their handlers, having a progressive condition (e.g., muscular dystrophy, multiple sclerosis) was an important moderator of whether having a service dog was associated with higher positive affect (46).

Emerging research also suggests that human genetic differences may play a key role in the study of human-animal interactions. A recent 2019 study indicated that there may be a genetic and heritable component for choosing to have a pet (47). Specifically, researchers examined pet dog ownership among over 35,000 pairs of twins in Sweden and found that more than 50% of the variability in whether an individual owned a dog at the time of the study was explained by genetics. Although the specific genes associated with dog ownership could not be identified, this research suggests that a combination of environmental and genetic influences could influence an individual's affinity toward animals. Genetic variability is also an important consideration in research incorporating hormones and/or neuropeptides such as oxytocin and cortisol. Variations in the oxytocin receptor gene have been associated with human attachment behavior (48) and caregiving styles (49), and recently have been demonstrated to be associated with dog-owner attachment (50). Similarly, there are many sources of genetic and environmental influence on cortisol synthesis, metabolism, and reactivity (51, 52).

Finally, it is also important to consider differences in human experiences, thoughts, and behavior that may contribute to variable outcomes from HAI. Research suggests that interactions and relationships with companion animals can be impacted by human personality traits (53, 54). In addition, human attachment styles (e.g., avoidant or anxious attachment) can be important in understanding variation in the human-animal bond. For example, studies have shown that pet owners with avoidant attachment to their pets experience less stress-reducing benefits from their pets (55) and report negative expectations about a pet's availability and responsiveness (56). Quality and quantity of previous animal interaction, which is often unaccounted for in HAI research (5), is another important aspect of inter-participant variability. Future HAI research should be mindful of these differing experiences, including previous and current pet ownership as well as any fears or aversions toward animals, in both the design and analysis of studies.

VARIABILITY IN ANIMAL PARTICIPANTS IN HAI RESEARCH

Not only is there unique variation in human participants that needs to be accounted for, but also in animal participants.

Animals' temperament, personality, training, and even physiology are becoming increasingly important considerations in understanding variability in HAI research. Of course, there is wide variability in the species of animals studied in this field (e.g., mammals, birds, exotics, farm animals) that contributes to heterogeneity across studies (57). However, even within a single species, there is also variability in animals' appearance, disposition, rearing/training, and history of human interaction that may influence outcomes (58). As the animal itself is a key component of HAI, detailed descriptions and considerations of animal characteristics are critical to disentangling potential mechanisms of benefits (12). In the case of AAI, a consideration of animals' varying qualities also parallels the increasing acceptance of animals as individual agents rather than tools or objects (59, 60). Researchers should also be mindful of the fact that the animal's handler during an AAI session will also vary in their experience and knowledge regarding animal welfare as an additional source of variation (61).

As one of the most commonly studied companion animals in HAI research, dogs in particular exhibit a wide range of characteristics that contribute to variability. With a variety of breeds and sizes of dogs incorporated into companion, therapy, and assistance roles, individual differences in dogs' morphology and disposition are important aspects of variation in HAI literature. For example, physical traits such as a dog's size, coat, eye color, and ear shape have been shown to impact the way that humans perceive dogs (62, 63). In addition, different breeds of dogs can significantly differ in their temperament and behavior (64, 65). For example, some breeds may be more likely to make spontaneous eye contact (66), follow human communicative gestures (67) and be more sociable or playful with humans (68) than others. Even dogs of the same breed category can differ in personality characteristics including playfulness, curiosity, and sociability (69). These individual differences may impact the way that a dog, whether in a pet, therapy, or assistance role, interacts with and potentially bond with humans in the short-term or long-term (70). In the case of pet dogs, studies have found that owners of large dogs spend more time walking their dogs (71) and engage in more training and play with their dogs (72) while small breeds are reported to have more behavioral problems (73). In fact, considering breed-specific variation in analyses is an essential step toward understanding how genetic, physical, and behavioral differences in dogs may explain or predict human therapeutic outcomes. For example, a recent study tracking over 180,000 heart attack victims and 150,000 stroke victims found that dog owners had a lower risk of mortality than non-dog owners (74). However, results varied when considering the breed and size of dogs. Owning a pure-bred retriever breed, for example, was associated with a 40% decrease in mortality rates among the heart attack victims, while owning a companion/toy breed or mixed breed dog had no association with a reduction in mortality (75).

Emerging research has also quantified how differences in dogs' physiological profiles can influence the underlying therapeutic mechanisms of action during HAI. For example, a recent study showed that a population of service dogs selectively bred for friendly and non-aggressive temperaments had higher circulating levels of oxytocin, a neuropeptide involved in human-canine

social interaction and bonding, compared to pet dogs who were not selectively bred (76). Other studies have found that dogs' variation in their oxytocin receptor gene is related to certain breeds of dogs' social behavior when greeting unfamiliar people (77, 78) as well as dogs' attachment behaviors directed to their owners (50). As the oxytocin pathway has been discussed as a potential mechanism underlying positive human-dog interactions (79, 80), these individual differences across dogs may be important for understanding variability across studies.

VARIABILITY IN HUMAN-ANIMAL INTERACTIONS

Thus far, we have discussed variability in both human and animal participants that may contribute to observed variability across HAI research findings. However, one of the most truly variable aspects of this research lies in the nature of the human-animal interactions themselves (i.e., the physical, emotional, and/or psychological interactions that a human and an animal share). In research quantifying the benefits of pet ownership, a specific challenge lies in defining "ownership" and accounting for the variability surrounding this term (81). For example, the human-animal relationship and its resulting effects may differ between those who provide a caregiving role to the animal and those who simply cohabitate with the animal. Dogs, in particular, may also fill several different roles across households including serving as a companion, a surrogate child, or strictly for tasks such as hunting or guarding (82). It is similarly important to consider the varying length of cohabitation time and how much time a human-pet dyad spends together on a daily basis– both of which may have a significant impact on outcomes (83). Not only does the quantity of time have implications for research, but so does the quality of the interactions between an individual and a pet. For example, there is complex variation in daily dog-owner interactions that may contribute to the strength of the human-animal bond ranging from co-sleeping to frequency of cooperative activities such as play or training [e.g., (84, 85)]. Dogs have also been found to form unique attachment relationships to their owners [e.g., avoidant or anxious; (86)] that may be impacted by their owner's caregiving and/or own attachment styles [e.g., (87)]. These sources of heterogeneity have prompted researchers to use a dyadic approach to consider both the attributes of pets and owners to holistically evaluate human-animal relationships (88).

In research assessing outcomes from AAI, interactions can vary widely in terms of activities (e.g., structured or unstructured), setting (e.g., hospital bed, classroom, outdoors), human to animal ratio (e.g., group or individual interaction), and human-animal contact (e.g., duration of petting, talking, or walking). Because of this considerable variation, there is a critical need for manualized protocols and/or detailed reporting of procedures and interactions across studies (89). This will allow for a greater understanding of the benefits from AAI are due specifically to the animal's presence or to other aspects of the intervention such as novelty, attention, or human interaction (12).

During AAI, not only do the components of the interaction contribute to variability, but so does the "dosage" of the intervention in terms of total time spent interacting with an animal. For example, in a systematic review of the effects of AAI for individuals with dementia, the duration of contact with the therapy animal spanned from three, 10-min interactions in one study to bimonthly interactions over 2 years in another (26). In addition, details regarding intervention length, frequency, and content are sometimes not reported. A systematic review of AAI for trauma found that while most articles reported some aspects of the procedures surrounding the participant-animal interaction, not a single article provided enough detail to allow for replication (90). When comparing findings across studies, the omission of these critical details makes it impossible to determine the potential sources of methodological variation. Therefore, it is important for researchers to provide sufficient detail surrounding the characteristics of human-animal interaction, especially in AAI studies, to address this source of variability.

A DISCUSSION OF THE VARIABILITY EXPLAINED BY THE UNIQUE NATURE OF HAI

There is inherent variability linked to the unique nature of HAI, in that, in its simplest form, it involves two complex organisms, a human and a companion animal, interacting in dynamic ways. Not only does HAI research need to account for human psychological, sociological, physiological, and economic variability across humans, but these same variable characteristics apply to the animal as well. For example, a person with financial resources, time, and or motivation to do so, may provide excellent veterinary care, high-quality nutrition, and opportunities for life enrichment to their companion animal that another person with fewer financial resources, less available time, or less motivation may provide to the same species of companion animal. It is important to note that this example is not intended to imply that wealthy people are better caretakers of their companion animals, but rather that each of these variables (financial resources, time, and motivation) are likely to play a role in the care and life enrichment of companion animals that will contribute to variability in pet ownership research. Further, developmental changes must also be taken into consideration. Not only will children interact differently with companion animals than adults and older adults, but each developmental stage may bring a host of unique needs or desires to human relationships with companion animals. On the other side, we cannot neglect the developmental changes taking place in the companion animals as well. Not only will animals also experience physiological, psychological, and behavioral changes as they develop, but also may gain a better understanding of their human counterparts or develop fears or aversions to humans. Therefore, not only do researchers need to keep in mind the inherent variability of the unique nature of HAI, but also how it evolves in both humans and animals over time.

As a field, HAI is charged with understanding not one, but two complex creatures, each with their own needs, motivations,

and capabilities. On the human side, individuals will vary in their experiences, attitudes, abilities, and personalities that shape the way that they perceive, interact with, and ultimately bond with an animal. The animal side of the equation is further complicated by multiple species, each with different species-specific behaviors, welfare needs, physical and mental capabilities, housing and enrichment requirements, and zoonotic disease concerns. Even within the same species, there is immense additional variability in the individual (e.g., breed, temperament, personality, and behavior) that will influence its relationship and interactions with humans. Therefore, research in this field must be mindful of all of these complexities, each of which contribute to the multifaceted nature of human-animal interaction.

While the inherent variability in HAI research contributes to a unique complexity that makes for an interesting field of study, it also makes the field particularly challenging. In particular, a broad spectrum of theoretical considerations is required to account for the variability in the human, the animal, the types of interactions possible, the dynamics of the actual interaction, and any potential constraints imposed by the setting of the interaction (e.g., educational, healthcare). To achieve this, an equally broad spectrum of research methodologies must be incorporated to capture the subtle nuances of the interactions (e.g., qualitative methods) and to tightly control as many aspects of the interactions as possible (e.g., experimental methods).

CONCLUSION AND FUTURE DIRECTIONS

In conclusion, we have described how variability in methods and measurement, human participants, animal participants, and interactions may contribute to mixed findings in the field of human-animal interaction. We have also made suggestions on how to address this variability by using appropriate experimental designs and/or statistical analyses to account for confounding variables, by ensuring detailed reporting of both human and animal characteristics, and by providing thorough descriptions of the duration, context, and structure of human-animal interactions including replicable and/or manualized AAI procedures when possible. However, we have also discussed the inherent complexity of HAI in that even the simplest research study involves considering the dynamic interaction of two complex beings, an animal and a human.

To address the complexity of the field of HAI, researchers must face a variety of theoretical and methodological considerations to account for multiple sources of variability and individual characteristics on both the animal and human level. However, the basic tenets of science apply regardless of the complexity of the topic under study. The field of HAI demands a wide variety of methodologies and measurement, each of which provides important and useful information on which to build the field. However, whatever the approach, the experimental design must be appropriate for the research question and conclusions drawn must be mindful of limitations, including unaccounted for variability that may impact or contextualize findings. It is also incumbent upon researchers to report all results, even nonsignificant findings, as understanding the individuals, contexts, and conditions in which HAI is not beneficial is equally important for the progression of the field.

Although the field of HAI has been characterized by mixed findings, there is a wealth of promising information available on which to expand. With the growth of research in this field, new frameworks continue to emerge to study the relationships between humans and companion animals such as the dyadic approach (88), trans-species methodology (91) and the biopsychosocial model (Gee et al., under review). Inspiration from other fields, such as social psychology (92) developmental psychology (93, 94) and social neuroscience (95), will also continue to inform the theoretical underpinnings of human-animal interactions. The field will continue to benefit from an accumulation of rigorous science while building viable and testable theories. With increased funding opportunities from both public and private sources, knowledge regarding the potential therapeutic outcomes from animal interaction will continue to strengthen by incorporating randomized clinical trial designs and large-scale population studies (96). Although it is a young field, HAI has a promising foundation on which to build, and a firm commitment to scientific rigor will secure its future.

AUTHOR CONTRIBUTIONS

KR, HH, and NG equally contributed to the formation of the manuscript's conceptual ideas and framework. All authors contributed to writing and editing the manuscript.

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REFERENCES

1. Hines LM. Historical perspectives on the human-animal bond. *Am Behav Sci.* (2003) 47:7–15. doi: 10.1177/0002764203255206
2. Friedmann E, Katcher AH, Lynch JJ, Thomas SA. Animal companions and one-year survival of patients after discharge from a coronary care unit. *Public Health Rep.* (1980) 95:307–12.
3. Allen KM, Blascovich J, Tomaka J, Kelsey RM. Presence of human friends and pet dogs as moderators of autonomic responses to stress in women. *J Person Soc Psychol.* (1991) 61:582–9. doi: 10.1037/0022-3514.61.4.582
4. The Animals and Society Institute (2020). *Degree Programs in Human-Animal Studies*. Available online : https://www.animalsandsociety.org/human-animal-studies/degree-programs/ (accessed September 9, 2020).
5. Serpell J, Mccune S, Gee N, Griffin JA. Current challenges to research on animal-assisted interventions. *Appl Dev Sci.* (2017) 21:223–33. doi: 10.1080/10888691.2016.1262775
6. Herzog H. The impact of pets on human health and psychological well-being: Fact, fiction, or hypothesis? *Curr Direct Psychol Sci.* (2011) 20:236–9. doi: 10.1177/0963721411415220
7. Gilbey A, Tani K. Companion animals and loneliness: a systematic review of quantitative studies. *Anthrozoös.* (2015) 28:181–97. doi: 10.1080/08927936.2015.11435396

8. Herzog H. *Can Pets Relieve Loneliness in the Age of Coronavirus? Animals and Us* (2020). Available online at: https://www.psychologytoday.com/us/blog/animals-and-us/202004/can-pets-relieve-loneliness-in-the-age-coronavirus (accessed April 13, 2020).

9. Urbanski BL, Lazenby M. Distress among hospitalized pediatric cancer patients modified by pet-therapy intervention to improve quality of life. *J Pediatr Oncol Nursing* . (2012) 29:272–82. doi: 10.1177/1043454212455697

10. Chubak J, Hawkes R, Dudzik C, Foose-Foster JM, Eaton L, Johnson RH, et al. Pilot study of therapy dog visits for inpatient youth with cancer. *J Pediatr Oncol Nurs.* (2017) 34:331–41. doi: 10.1177/1043454217712983

11. Mccullough A, Ruehrdanz A, Jenkins MA, Gilmer MJ, Olson J, Pawar A, et al. Measuring the effects of an animal-assisted intervention for pediatric oncology patients and their parents: a multisite randomized controlled trial. *J Pediatr Oncol Nurs.* (2018) 35:159–77. doi: 10.1177/1043454217748586

12. Marino L. Construct validity of animal-assisted therapy and activities: how important is the animal in AAT? *Anthrozoös.* (2012) 25:139–51. doi: 10.2752/175303712X13353430377219

13. Turner DC, Rowan AN, Herzog H, Mccune S, Kruger KA, Griffin JA, et al. A Glimpse at the future of animal-assisted interventions: Selected commentaries. In: Fine AH, editor. *Handbook On Animal Assisted Therapy: Theoretical Foundations and Guidelines for Practice.* 4th ed. Academic Press (2015). p. 391–414.

14. Open Science Collaboration. Estimating the reproducibility of psychological science. *Science.* (2015) 349:aac4716. doi: 10.1126/science.aac4716

15. Nave G, Camerer C, Mccullough M. Does oxytocin increase trust in humans? A critical review of research. *Perspect Psychol Sci.* (2015) 10:772–89. doi: 10.1177/1745691615600138

16. Jones BC, Hahn AC, Debruine LM. Ovulation, sex hormones, and women's mating psychology. *Trends Cogn Sci.* (2019) 23:51–62. doi: 10.1016/j.tics.2018.10.008

17. Inzlicht M, Friese M. The past, present, and future of ego depletion. *Social Psychol.* (2019) 50:370–8. doi: 10.1027/1864-9335/a000398

18. Herrera-Perez D, Haslam A, Crain T, Gill J, Livingston C, Kaestner V, et al. Meta-Research: a comprehensive review of randomized clinical trials in three medical journals reveals 396 medical reversals. *Elife.* (2019) 8:e45183. doi: 10.7554/eLife.45183

19. Steinert C, Hofmann M, Leichsenring F, Kruse J. The course of PTSD in naturalistic long-term studies: high variability of outcomes. A systematic review. *Nord J Psychiatry.* (2015) 69:483–96. doi: 10.3109/08039488.2015.1005023

20. Sautenet B, Cho Y, Gutman T, Rangan G, Ong A, Chapman AB, et al. Range and variability of outcomes reported in randomized trials conducted in patients with polycystic kidney disease: a systematic review. *Am J Kidney Dis.* (2020) 76:213–23. doi: 10.1053/j.ajkd.2019.12.003

21. Lukenchuk J, Sims LA, Shin JJ. Variability in outcome reporting for operatively managed anterior glenohumeral instability: a systematic review. *Arthroscopy.* (2017) 33:477–83. doi: 10.1016/j.arthro.2016.07.027

22. Ioannidis JP. Why most published research findings are false. *PLoS Med.* (2005) 2:e124. doi: 10.1371/journal.pmed.0020124

23. Germain SM, Wilkie KD, Milbourne VM, Theule J. Animal-assisted psychotherapy and trauma: A meta-analysis. *Anthrozoös.* (2018) 31:141–64. doi: 10.1080/08927936.2018.1434044

24. Duindam HM, Asscher JJ, Hoeve M, Stams GJJ, Creemers HE. Are we barking up the right tree? A meta-analysis on the effectiveness of prison-based dog programs *Crim Just Behav.* (2020) 47:749–67. doi: 10.1177/0093854820909875

25. Mccune S, Kruger KA, Griffin JA, Esposito L, Freund LS, Hurley KJ, et al. Evolution of research into the mutual benefits of human–animal interaction. *Anim Front.* (2014) 4:49–58. doi: 10.2527/af.2014-0022

26. Yakimicki ML, Edwards NE, Richards E, Beck AM. Animal-assisted intervention and dementia: a systematic review. *Clin Nurs Res.* (2018) 28:9–29. doi: 10.1177/1054773818756987

27. Gee NR, Mueller MK. A systematic review of research on pet ownership and animal interactions among older adults. *Anthrozoös.* (2019) 32:183–207. doi: 10.1080/08927936.2019.1569903

28. Zafra-Tanaka JH, Pacheco-Barrios K, Tellez WA, Taype-Rondan A. Effects of dog-assisted therapy in adults with dementia: a systematic review and meta-analysis. *BMC Psychiatry.* (2019) 19:41. doi: 10.1186/s12888-018-2009-z

29. Maujean A, Pepping CA, Kendall E. A systematic review of randomized controlled trials of animal-assisted therapy on psychosocial outcomes. *Anthrozoös.* (2015) 28:23–36. doi: 10.2752/089279315X1412935072 1812

30. Waite TC, Hamilton L, O'brien W. A meta-analysis of animal assisted interventions targeting pain, anxiety and distress in medical settings. *Comp Ther Clin Pract.* (2018) 33:49–55. doi: 10.1016/j.ctcp.2018.07.006

31. Hall SS, Gee NR, Mills DS. Children reading to dogs: a systematic review of the literature. *PLoS ONE.* (2016) 11:e0149759. doi: 10.1371/journal.pone.0149759

32. O'haire ME. Animal-assisted intervention for autism spectrum disorder: a systematic literature review. *J Autism Dev Disord.* (2013) 43:1606–22. doi: 10.1007/s10803-012-1 707-5

33. Wilson CC, Netting FE. The status of instrument development in the human–animal interaction field. *Anthrozoös.* (2012) 25:s11–55. doi: 10.2752/175303712X13353430376977

34. Gilbey A, Tani K. Pets and loneliness: examining the efficacy of a popular measurement instrument. *Anthrozoös.* (2020) 33:529–46. doi: 10.1080/08927936.2020.1771058

35. Nimer J, Lundahl B. Animal-assisted therapy: a meta-analysis. *Anthrozoös.* (2007) 20:225–38. doi: 10.2752/089279307X224773

36. Miller SC, Kennedy CC, Devoe DC, Hickey M, Nelson T, Kogan L. An examination of changes in oxytocin levels in men and women before and after interaction with a bonded dog. *Anthrozoös.* (2009) 22:31–42. doi: 10.2752/175303708X390455

37. Herzog HA. Gender differences in human–animal interactions: a review. *Anthrozoös.* (2007) 20:7–21. doi: 10.2752/089279307780216687

38. Crossman MK, Kazdin AE. Perceptions of animal-assisted interventions: the influence of attitudes toward companion animals. *J Clin Psychol.* (2018) 74:566–78. doi: 10.1002/jclp.22548

39. Jegatheesan B. Influence of cultural and religious factors on attitudes towards animals. In: Fine AH, editor. *Handbook On Animal Assisted Therapy: Theoretical Foundations and Guidelines for Practice.* 4th ed. Academic Press (2015). p. 37–41.

40. Valiyamattam G, Yamamoto M, Fanucchi L, Wang F. Multicultural considerations in animal-assisted intervention. *Hum Anim Interact Bull.* (2018) 6:82–104. Available online at: https://www.apa-hai.org/human-animal-interaction/haib/download-info/multicultural-considerations-in-aai/

41. Kazdin AE. Methodological standards and strategies for establishing the evidence base of animal-assisted therapies. In: Fine AH, editor. *Handbook on Animal-Assisted Therapy: Foundations and Guidelines for Animal-Assisted Interventions.* 4th ed. Academic Press (2015). p. 377–90.

42. Purewal R, Christley R, Kordas K, Joinson C, Meints K, Gee N, et al. Companion animals and child/adolescent development: a systematic review of the evidence. *Int J Environ Res Public Health.* (2017) 14:234. doi: 10.3390/ijerph14030234

43. Thorpe RJ, Kelley JA. Epidemiological panel studies of older adults: new frontiers in the research on human–animal interaction. *Anthrozoös.* (2019) 32:209–20. doi: 10.1080/08927936.2019.1569904

44. O'haire ME. Companion animals and human health: benefits, challenges, and the road ahead. *J Vet Behav Clin Appl Res.* (2010) 5:226–34. doi: 10.1016/j.jveb.2010.02.002

45. Hill J, Ziviani J, Driscoll C, Cawdell-Smith J. Can canine-assisted interventions affect the social behaviours of children on the autism spectrum? A systematic review. *Rev J Autism Dev Disord.* (2019) 6:13–25. doi: 10.1007/s40489-018-0151-7

46. Collins DM, Fitzgerald SG, Sachs-Ericsson N, Scherer M, Cooper RA, Boninger ML. Psychosocial well-being and community participation of service dog partners. *Disabil Rehabil Assist Technol.* (2006) 1:41–8. doi: 10.1080/09638280500167183

47. Fall T, Kuja-Halkola R, Dobney K, Westgarth C, Magnusson PK. Evidence of large genetic influences on dog ownership in the Swedish Twin Registry has implications for understanding domestication and health associations. *Sci Rep.* (2019) 9:7554. doi: 10.1038/s41598-019-44083-9

48. Chen FS, Barth M, Johnson SL, Gotlib IH, Johnson SC. Oxytocin receptor (OXTR) polymorphisms and attachment in human infants. *Front Psychol.* (2011) 2:200. doi: 10.3389/fpsyg.2011.00200

49. Bakermans-Kranenburg MJ, Van Ijzendoorn MH. Oxytocin receptor (OXTR) and serotonin transporter (5-HTT) genes associated with observed parenting. *Soc Cogn Affect Neurosci.* (2008) 3:128–34. doi: 10.1093/scan/nsn004

50. Kovács K, Virányi Z, Kis A, Turcsán B, Hudecz Á, Marmota MT, et al. Dog-owner attachment is associated with oxytocin receptor gene polymorphisms in both parties. A comparative study on austrian and hungarian border collies. *Front Psychol.* (2018) 9:435. doi: 10.3389/fpsyg.2018.00435

51. Bartels M, Van Den Berg M, Sluyter F, Boomsma D, De Geus EJ. Heritability of cortisol levels: review and simultaneous analysis of twin studies. *Psychoneuroendocrinology.* (2003) 28:121–37. doi: 10.1016/S0306-4530(02)00003-3

52. Kudielka BM, Hellhammer DH, Wüst S. Why do we respond so differently? Reviewing determinants of human salivary cortisol responses to challenge. *Psychoneuroendocrinology.* (2009) 34:2–18. doi: 10.1016/j.psyneuen.2008.10.004

53. Bagley DK, Gonsman VL. Pet attachment and personality type. *Anthrozoös.* (2005) 18:28–42. doi: 10.2752/089279305785594333

54. Reevy GM, Delgado MM. Are emotionally attached companion animal caregivers conscientious and neurotic? Factors that affect the human–companion animal relationship. *J Appl Anim Welf Sci.* (2015) 18:239–58. doi: 10.1080/10888705.2014.988333

55. Zilcha-Mano S, Mikulincer M, Shaver PR. Pets as safe havens and secure bases: the moderating role of pet attachment orientations. *J Res Person.* (2012) 46:571–80. doi: 10.1016/j.jrp.2012.06.005

56. Zilcha-Mano S, Mikulincer M, Shaver PR. An attachment perspective on human–pet relationships: conceptualization and assessment of pet attachment orientations. *J Res Person.* (2011) 45:345–57. doi: 10.1016/j.jrp.2011.04.001

57. Ng Z, Morse L, Albright J, Viera A, Souza M. Describing the use of animals in animal-assisted intervention research. *J Appl Anim Welf Sci.* (2019) 22:364–76. doi: 10.1080/10888705.2018.1524765

58. Hart LA. Methods, standards, guidelines, and considerations in selecting animals for animal-assisted therapy: Part A: Understanding animal behavior, species, and temperament as applied to interactions with specific populations. In: Fine AH, editor. *Handbook on Animal-Assisted Therapy: Theoretical Foundations and Guidelines for Practice.* 1st ed. Academic Press (2000). p. 81–97.

59. Kruger KA, Serpell JA. Animal-assisted interventions in mental health: Definitions and theoretical foundations. In: Fine AH, editor. *Handbook on Animal-Assisted Therapy: Theoretical Foundations and Guidelines for Practice.* 3rd ed. San Diego, CA: Academic Press (2010). p. 33–48.

60. Vitztum C, Urbanik J. Assessing the dog: a theoretical analysis of the companion animal's actions in human-animal interactions. *Soc Anim.* (2016) 24:172–85. doi: 10.1163/15685306-12341399

61. Granger B, Kogan L. Characteristics of animal-assisted therapy/activity in specialized settings. In: Fine AH, editor. *Handbook On Animal-Assisted Therapy Theoretical Foundations and Guidelines for Practice.* 2nd ed. Academic Press (2006). p. 263–285.

62. Gazzano A, Zilocchi M, Massoni E, Mariti C. Dogs' features strongly affect people's feelings and behavior toward them. *J Vet Behav.* (2013) 8:213–20. doi: 10.1016/j.jveb.2012.10.005

63. Hecht J, Horowitz A. Seeing dogs: Human preferences for dog physical attributes. *Anthrozoös.* (2015) 28:153–63. doi: 10.2752/089279315X14129350722217

64. Serpell JA, Duffy DL. Dog breeds and their behavior. In: Horowitz A, editor. *Domestic Dog Cognition and Behavior: The Scientific Study of Canis familiaris.* Springer (2014). p. 31–57.

65. Maclean EL, Snyder-Mackler N, Vonholdt BM, Serpell JA. Highly heritable and functionally relevant breed differences in dog behaviour. *Proc R Soc B.* (2019) 286:20190716. doi: 10.1098/rspb.2019.0716

66. Konno A, Romero T, Inoue-Murayama M, Saito A, Hasegawa T. Dog breed differences in visual communication with humans. *PLoS ONE.* (2016) 11:e0164760. doi: 10.1371/journal.pone.0164760

67. Wobber V, Hare B, Koler-Matznick J, Wrangham R, Tomasello M. Breed differences in domestic dogs'(Canis familiaris) comprehension of human communicative signals. *Interact Stud.* (2009) 10:206–24. doi: 10.1075/is.10.2.06wob

68. Asp HE, Fikse WF, Nilsson K, Strandberg E. Breed differences in everyday behaviour of dogs. *Appl Anim Behav Sci.* (2015) 169:69–77. doi: 10.1016/j.applanim.2015.04.010

69. Svartberg K, Forkman B. Personality traits in the domestic dog (*Canis familiaris*). *Appl Anim Behav Sci.* (2002) 79:133–55. doi: 10.1016/S0168-1591(02)00121-1

70. Borgi M, Cirulli F. Pet face: mechanisms underlying human-animal relationships. *Front Psychol.* (2016) 7:298. doi: 10.3389/fpsyg.2016.00298

71. Westgarth C, Christian HE, Christley RM. Factors associated with daily walking of dogs. *BMC Vet Res.* (2015) 11:116. doi: 10.1186/s12917-015-0434-5

72. Arhant C, Bubna-Littitz H, Bartels A, Futschik A, Troxler J. Behaviour of smaller and larger dogs: effects of training methods, inconsistency of owner behaviour and level of engagement in activities with the dog. *Appl Anim Behav Sci.* (2010) 123:131–42. doi: 10.1016/j.applanim.2010.01.003

73. Mcgreevy PD, Georgevsky D, Carrasco J, Valenzuela M, Duffy DL, Serpell JA. Dog behavior co-varies with height, bodyweight and skull shape. *PLoS ONE.* (2013) 8:e80529. doi: 10.1371/journal.pone.0080529

74. Mubanga M, Byberg L, Egenvall A, Ingelsson E, Fall T. Dog ownership and survival after a major cardiovascular event: a register-based prospective study. *Circ Cardiovas Qual Outcomes.* (2019) 12:e005342. doi: 10.1161/CIRCOUTCOMES.118.005342

75. Herzog H. *Do Purebreds (But Not Mutts) Reduce Dog Owner Death Rates?* (2019). Available online at: https://www.psychologytoday.com/us/blog/animals-and-us/201910/do-purebreds-not-mutts-reduce-dog-owner-death-rates (accessed September 13, 2020).

76. Maclean EL, Gesquiere LR, Gruen ME, Sherman BL, Martin WL, Carter CS. Endogenous oxytocin, vasopressin, and aggression in domestic dogs. *Front Psychol.* (2017) 8:1613. doi: 10.3389/fpsyg.2017.01613

77. Kis A, Bence M, Lakatos G, Pergel E, Turcsán B, Pluijmakers J, et al. Oxytocin receptor gene polymorphisms are associated with human directed social behavior in dogs (*Canis familiaris*). *PLoS ONE.* (2014) 9:e83993. doi: 10.1371/journal.pone.0083993

78. Kubinyi E, Bence M, Koller D, Wan M, Pergel E, Ronai Z, et al. Oxytocin and opioid receptor gene polymorphisms associated with greeting behavior in dogs. *Front Psychol.* (2017) 8:1520. doi: 10.3389/fpsyg.2017.01520

79. Maclean EL, Hare B. Dogs hijack the human bonding pathway. *Science.* (2015) 348:280–1. doi: 10.1126/science.aab1200

80. Marshall-Pescini S, Schaebs FS, Gaugg A, Meinert A, Deschner T, Range F. The role of oxytocin in the dog–owner relationship. *Animals.* (2019) 9:792. doi: 10.3390/ani9100792

81. Friedmann E, Gee NR. Critical review of research methods used to consider the impact of human–animal interaction on older adults' health. *Gerontologist.* (2019) 59:964–72. doi: 10.1093/geront/gnx150

82. Blouin DD. Are dogs children, companions, or just animals? Understanding variations in people's orientations toward animals. *Anthrozoös.* (2013) 26:279–94. doi: 10.2752/175303713X13636846944402

83. Dotson MJ, Hyatt EM. Understanding dog–human companionship. *J Buss Res.* (2008) 61:457–66. doi: 10.1016/j.jbusres.2007.07.019

84. Bennett PC, Trigg JL, Godber T, Brown C. An experience sampling approach to investigating associations between pet presence and indicators of psychological wellbeing and mood in older australians. *Anthrozoös.* (2015) 28:403–20. doi: 10.1080/08927936.2015.1052266

85. Lafollette MR, Rodriguez KE, Ogata N, O'haire ME. Military veterans and their PTSD service dogs: associations between training methods, PTSD severity, dog behavior, and the human-animal bond. *Front Vet Sci.* (2019) 6:23. doi: 10.3389/fvets.2019.00023

86. Previde EP, Valsecchi P. The immaterial cord: the dog–human attachment bond. In: Kaminski J, Marshall-Pescini S, editors. *The Social Dog: Behavior and Cognition.* Academic Press (2014). p. 165–89.

87. Siniscalchi M, Stipo C, Quaranta A. "Like Owner, Like Dog": correlation between the owner's attachment profile and the owner-dog bond. *PLoS ONE.* (2013) 8:e78455. doi: 10.1371/journal.pone.0078455

88. Rehn T, Keeling LJ. Measuring dog-owner relationships: crossing boundaries between animal behaviour and human psychology. *Appl Anim Behav Sci.* (2016) 183:1–9. doi: 10.1016/j.applanim.2016.07.003

89. Griffin JA, Hurley K, Mccune S. Opinion: human-animal interaction research: progress and possibilities. *Front Psychol.* (2019) 10:2803. doi: 10.3389/fpsyg.2019.02803

90. O'haire ME, Guérin NA, Kirkham AC. Animal-assisted intervention for trauma: a systematic literature review. *Front Psychol.* (2015) 6:1121. doi: 10.3389/fpsyg.2015.01121

91. Franklin A, Emmison M, Haraway D, Travers M. Investigating the therapeutic benefits of companion animals: problems and challenges. *Qual Sociol Rev.* (2007) 3:42–58.

92. Dhont K, Hodson G, Loughnan S, Amiot CE. *Rethinking Human-Animal Relations: The Critical Role of Social Psychology*. London: SAGE Publications Sage UK (2019).

93. Yorke J. The significance of human–animal relationships as modulators of trauma effects in children: A developmental neurobiological perspective. *Early Child Dev Care.* (2010) 180:559–70. doi: 10.1080/03004430802181189

94. Pachana NA, Massavelli BM, Robleda-Gomez S. A developmental psychological perspective on the human–animal bond. In: Blazina C, Boyraz G, Shen-Miller D, editors. *The Psychology of the Human-Animal Bond: A Resource for Clinicians and Researchers*. Springer (2011). p. 151–65.

95. Pendry P, Vandagriff JL. Salivary studies of the social neuroscience of human-animal interaction. In: Granger D, Taylor MK, editors. *Salivary Bioscience:*

Foundations of Interdisciplinary Saliva Research and Applications. Springer (2020). p. 555–81.

96. Mccune S, Mccardle P, Griffin JA, Esposito L, Hurley K, Bures R, et al. Editorial: Human-Animal Interaction (HAI) Research: a decade of progress. *Front Vet Sci.* (2020) 7:44. doi: 10.3389/fvets.2020. 00044

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