Changes in the Activity Levels and Physiological Welfare of Dogs Pre- and Post-Adoption

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Abstract

Numerous potential stressors that are present in the animal shelter are often absent or less intense in the home, which can lead to changes in adopted dogs' behavior, activity, and overall welfare. Given notable differences between these environments, dogs' activity or behavior in the shelter may not necessarily reflect that in a home. Instead, this behavior may be indicative of the dog's welfare while being sheltered. Our study utilized a within-subjects design to examine how dogs' activity, physiology, and perceptions of their behavior change within and between the shelter and home environments. To evaluate this, 19 dogs wore PetPace Health Monitoring collars to measure their activity and physiology across each of their final 20 days in the shelter and their first 20 days post-placement into a home. Dogs' activity was measured each minute using an accelerometer, while dogs' pulse, heart rate variability (HRV), and respiration were measured using an acoustic sensor within these collars. A modified C-BARQ was completed by care staff in the shelter three weeks post-intake and adopters and caregivers in the home three weeks post-placement to evaluate dogs' behavior and activity in both environments.

Our results revealed that, while living in a home, dogs had significantly lower pulse and respiration rates, as well as higher HRV, than when they were in the shelter. Dogs also spent, most significantly, more time resting and less time in high activity in their homes as compared to the shelter. Each day in the home, dogs' rate of rest significantly increased by 1.2%, while their rate of high activity decreased by 5.6% in the home and 1.8% in the shelter. Care staff in the shelter and caregivers in the home also reported significant differences in dogs' behavior, although reports of behavior remained mild in both environments. Most notably, dogs displayed

greater fear-based and aggression-related behaviors in the home, while their excitability was higher towards visitors in the shelter. Additionally, we found that both care staff and caregivers underestimated how much time dogs spent resting while also overestimating the amount of time dogs spent in higher levels of activity.

Taken together, the increase in dogs' rest and decrease in their high activity in a home, combined with improvements in pulse and respiration rates and heart rate variability, provide compelling evidence of the positive change in welfare dogs experience in a home. Furthermore, these results support the use of activity monitoring as a means of evaluating the welfare of shelter-living dogs. Underestimations by staff of dogs' perceived rest and overestimations of their high activity highlight the advantages of continuous monitoring technologies for canine welfare assessment. Moreover, differences in dogs' fear and aggression in the home, as compared to the shelter, reinforce the difficulty in predicting post-placement behavior. These results also further support the need for behavioral support programs for adopters and caregivers. Further considerations for interventions like foster care should be made, particularly for dogs that display elevated levels of high activity and reduced rest. Temporary placement with a caregiver might address these concerns and provide behavioral information in a home environment, offering potential support for both the immediate and long-term welfare of dogs in animal shelters.

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General Audience Abstract

The stress of the shelter environment can contribute to significant changes in the behavior and welfare of shelter-living dogs. As such, the behavior of dogs seen in shelters may not be predictive of a dog's behavior in a home post-adoption. To better understand the experiences of dogs in shelter and home environments, this study explored changes and connections in dogs' activity, behavior, and physiology pre- and post-adoption. Continuously worn PetPace Health Monitoring Collars measured changes in dogs' activity and physiological welfare, including respiration, pulse rates, and heart rate variability, for 19 dogs across their last 20 days in a shelter environment and first 20 days in an adopted or foster home. Additionally, a C-BARQ behavioral questionnaire was used to evaluate changes in reports of dogs' behavior prior to adoption in the shelter and post-adoption in the home. The results of the study revealed that dogs' physiological welfare, including respiration, pulse, and heart rate variability, improved in the home environment compared to time spent in the shelter. Furthermore, dogs spent significantly more time at rest and less time engaging in high levels of activity in the home, while elements of their behavior also changed between the environments. Taken together, these results provide further evidence of the positive impact that a home environment can have on a dog's welfare. Changes in dogs' activity and behavior post-adoption further indicate that a dog's behavior in a shelter may not be predictive of their behavior in a home. Shelter staff should consider foster care for dogs that are engaging in high levels of activity and spending little time at rest in the shelter, as these are likely indicators of a shelter-living dog's environmental stress. In doing so, shelter staff can provide dogs a break from shelter stressors, improve their immediate physiological welfare,

and gain more accurate information about behaviors and activity of a dog in a home environment, aiding in the success of their future placement in an adopted home.

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1.0 Introduction

1.1 Existing Stressors in Animal Shelters

Each year, millions of dogs enter animal shelters across the United States. Although the majority of dogs are successfully reunited with their owners or adopted, an estimated 14% of dogs in U.S. shelters are euthanized annually (Woodruff & Smith, 2019; Rowan & Kartal, 2018). The total number of animals entering shelters and being euthanized has declined across recent decades (ASPCA, 2025a). However, lengths of stay are likely increasing as animals are awaiting adoption or other live outcomes for longer periods of time (ASPCA, 2016; Shelter Animals Count, 2023). This increase in length of stay prolongs the animal's exposure to the shelter environment.

While in the shelter, dogs experience a host of environmental stressors that can compromise their welfare, including social isolation (Hennessy et al., 1997), confinement (Dalla Villa et al., 2013), excessive noise (Sales et al., 1997), reduced exercise opportunity (Hoffman et al., 2019), and lack of environmental control (Riggio, 2018). The following paragraphs will detail these stressors and their impact on the welfare of shelter-living dogs.

Kenneling in shelters contributes to stressors of confinement and social isolation, by severely restricting a dog's activity and opportunities for social interaction (Wells et al., 2002b). The physical space provided to dogs when confined to a kennel is often insufficient to allow shelter-living dogs to engage in species-typical activities (Hubrecht et al., 1995; Wells et al., 2002b). Additionally, while dogs are typically housed individually in shelters to minimize injury and disease transmission, this can lead to significant social isolation (Beerda et al., 1999a; Beerda et al., 1999b; Hennessy et al., 1997; Hubrecht, 1995).

Among the stressors presented in a shelter, excessive noise is a particularly salient component of a dogs' experience. The stress of the shelter environment causes excessive noise (i.e., barking), which can be amplified by the hard surfaces of the shelter and consistent human traffic from staff, volunteers, and the public (Coppola et al., 2006). Shelters typically expose dogs to intensely high noise levels, often surpassing 100 dB, which is above the 90 dB safety limit for human exposure over an eight-hour period (Sales et al., 1997; Coppola et al., 2006; Scheifele et al., 2012; Venn, 2013; United States Department of Labor, Occupational Health and Safety Administration, 1981; Wells et al., 2002a). Prolonged exposure to these noise levels has been documented to cause permanent hearing loss in dogs (Scheifele et al., 2012).

Another major stressor for shelter-living dogs is limited control and predictability over their daily experiences, particularly interactions with people and other animals (Hennessy et al., 1997). Dogs' lack of control within the environment can lead to reduced interest in interacting with visitors and retreating to the back of their kennels (Wells & Hepper, 1992; Wells et al., 2002b). Moreover, dogs often have little predictability regarding opportunities for walking, exercise, interaction, play, and enrichment (Hennessy et al., 1998). In other mammals, lack of predictability has been found to increase physiological and behavioral stress responses (e.g., Bassett & Smith, 2007).

Taken together, these limitations in shelter dogs' opportunity to engage in social interaction, reductions in adequate space, minimal choice or control in daily routines, and highly-demanding sensory input illustrate the extreme stress of the shelter environment. Dogs that are unable to adapt to these numerous shelter stressors often experience compromised welfare, or a reduced internal state as they attempt to cope with their environment (Broom, 2021).

Home environments can address many, if not all, of these potential stressors presented to shelter-living dogs. Home-housed dogs can often choose to engage in rest and moderate exercise throughout the day, as well as interact with other humans or animals; this allows for greater freedom of movement and exercise opportunities (Morrison et al., 2013). In both adopted and fostered homes, dogs also experience increased opportunity for consistent interaction with humans. As such, dogs also experience a higher likelihood of developing secure, healthy attachment styles to their caregiver in a home than shelter-living dogs develop with care staff in a shelter (Thielke & Udell, 2020). As a result, living in a home environment reduces social isolation, improves attachment, and increases species-typical behavior, therefore, improving the welfare of these dogs (Hubrecht, 1995; Morrison et al., 2013). The following sections outline previous research that has explored dogs' physiological welfare and activity with a focus on their experience in the animal shelter and home environment.

1.2 The Stress Response in Dogs

The stress response in dogs is initiated by the sympathetic nervous system (SNS), a component part of the autonomic nervous system. The SNS activates the sympathetic-adrenal-medullary (SAM) system, ultimately releasing adrenaline (epinephrine) and noradrenaline (norepinephrine) from the adrenal medulla into the bloodstream of the dog (Kaiser & Jaillardon, 2023). These hormones increase the body's preparation for acute and immediate action in a stressful situation, including a significant increase in heart rate, blood pressure, and respiration rate; these physiological changes help prepare the body for "fight or flight" (de Carvahlo et al., 2020).

At the same time, the hypothalamus-pituitary-adrenal axis (HPA) is activated to release corticotrophin-releasing hormone (CRH), which later signals the pituitary gland to release adrenocorticotrophic hormone (ACTH). ACTH activates release of cortisol from the adrenal glands, which helps manage the dog's stress response. Cortisol is essential for generating and controlling a stress response in the body - altering memory, generating instinctive responses, increasing the pain threshold, and changing metabolic and immune responses (Schwabe & Wolfe, 2009; 2010). When the threat of stress reduces, cortisol levels fall, and the body is able to return to typical functioning through a negative feedback loop; higher levels of cortisol signal that the HPA axis should shut off the stress response (Keller et al., 2021).

In the presence of a stressor, the sympathetic nervous system activates in all mammals, including dogs. As dogs enter the shelter and experience its myriad of stressors, for example, it is typical for their bodies to engage in activation of the HPA axis and SAM system leading to increases in heart rate, respiration rate, and release of cortisol as they adapt to this new environment and attempt to maintain physiological homeostasis (Marza et al., 2024). The other portion of the autonomic nervous system, known as the parasympathetic nervous system (PNS), is also engaged following a stress response. The PNS releases acetylcholine, which helps to counteract effects of cortisol and adrenaline in the body, decreasing heart rate, blood pressure, and respiration, while also relaxing muscles, increasing metabolism, and regulating the immune response (Linden Vet, 2024).

While an immediate, acute response to stress is normal and healthy for dogs, prolonged exposure to stressors in the shelter can lead to a more negative state of chronic stress (Beerda et al., 1999a; Beerda et al., 1999b). Lengthy exposure to stressors and an inability to adapt to the environment can contribute to hyperactivation of the HPA axis, producing high levels of cortisol that can damage areas of the brain and suppress the HPA axis over time (Ring et al., 2025). HPA axis suppression, in which high levels of cortisol reduce the stress response, can cause the negative feedback loop to malfunction. Over time, the entire stress response system can become impaired, leading to health concerns, psychological impacts, behavioral changes, and reduced welfare for the dog (Arndt et al., 2022; Mills et al., 2014).

1.3 Physiological Measures of Canine Stress

Historically, dogs' physiological welfare has often been studied by comparing changes in cortisol, a glucocorticoid hormone that plays an essential role in regulating the stress response in mammals, including dogs (Marza et al., 2024). More recently, other physiological measures (i.e., pulse, respiration, and heart rate variability) have also been utilized to understand canine welfare and their relationship with cortisol has been investigated. Cortisol levels simply indicate that the animal has reacted to a stimulus within its environment, but does not necessarily indicate whether that dogs' arousal is positively or negatively valenced without further behavioral or physiological context. Nevertheless, due to its role in HPA axis responding, this hormone is commonly used to indicate the stress levels of an animal (Marza et al., 2024).

Previous scientific literature has revealed that dogs living in a shelter have significantly higher cortisol levels compared to dogs living in homes (Gunter et al., 2019; van der Laan et al., 2023a). A study by Hennessy et al. (1997) found that, on dogs' first day in a shelter, their cortisol levels can be nearly three times higher than levels of a typical dog living in a home environment. Cortisol levels remain at this high level for the first three days in the shelter, gradually declining over time (Hennessy et al., 1997). Even so, they can remain elevated for weeks after a dog's arrival to the shelter, providing evidence of the challenges dogs experience adapting and living in this unpredictable environment (Stephen & Ledger, 2006; Rooney et al., 2007). Meanwhile, dogs that experience foster care for as little as one night, have significantly reduced cortisol levels in the home compared to their time in the shelter, indicating the importance of a home environment for reducing dogs' stress (Gunter et al., 2019; 2021, 2026).

Other physiological measures of stress in dogs include increased heart rate, elevated respiration, and decreased heart rate variability (de Carvahlo et al., 2020; Shaffer & Ginsberg, 2017). Changes in respiration rates can be observed visually through dogs' panting behaviors. As norepinephrine is released by the sympathetic nervous system of a dog, breathing becomes shallow and rapid to allow oxygen to enter airways faster and prepare the body for action (Smith & Cohen, 2025). As a result, dogs exposed to stressors, such as those in the shelter, can experience an increase in their overall respiration rate. The typical respiration rate for dogs is between 10 and 30 respirations per minute, depending on the activity type that the dog is engaging in. If dogs have a resting respiration rate above 30 per minute, this may be a sign of severe environmental or internal stress that may require behavioral or medical intervention (Bodnariu, 2008).

Heart rate has been previously measured as a means to understand the impacts of stressors on dogs. Dogs' experience constricting of the blood vessels, increases in blood pressure, and increases in heart rate when exposed to stressors, such as during their time in the shelter (de Carvahlo et al., 2020). Beerda et al. (1998) explored the behavioral and physiological responses of 10 dogs to novel stimuli in relation to their heart rate and salivary cortisol. The results revealed that dogs exhibited stress-induced behaviors (i.e., crouching, tail tucking, and restlessness) in response to stressful stimuli including shocks, loud sounds, and a novel falling bag. Meanwhile, dogs' heart rate increased quickly and returned to baseline levels eight minutes after exposure to the stimuli; salivary cortisol levels rose several minutes after exposure and returned to baseline within an hour (Beerda et al., 1998).

As the dogs' heart rate changes in response to stress, heart rate variability (HRV), or the variation in time between successive heartbeats, can also be impacted. Higher HRV, or greater variability in the time between heartbeats, is associated with activation of the parasympathetic nervous system and a return of the body to homeostatic or adaptive heart activity after stressful periods. Lower HRV, or lower variability in the time between heartbeats, is indicative of higher stress, prolonged elevation of heart rate with low variation, and activation of the sympathetic nervous system in response to stress (Shaffer & Ginsberg, 2017). Thus, the variability in intervals is generally associated with more or less adaptability to the demands in the environment and is a useful measure of the autonomic nervous system's ability to manage stress (Griffioen et al., 2023).

Heart rate variability is increasingly used as a tool to non-invasively understand the activation of the autonomic nervous system in dogs during a stress response, aiding in our understanding of their welfare and overall arousal levels (Bidoli et al., 2022). Several studies have explored the relationship between heart rate variability and emotional or environmental stress. Katayama et al. (2016) found that, when dogs are separated from their caregivers, HRV decreases significantly. Higher levels of emotional stress in response to different types of handling was also found to be associated with lower levels of HRV (Kuhne et al., 2014). Meanwhile, when presented with positive environmental enrichment in the shelter, like music, dogs' heart rate variability significantly increased (Amaya et al., 2020).

Bergamasco et al. (2010) explored the connection between HRV and salivary cortisol levels in shelter-living dogs by utilizing human-social interaction as an intervention for reducing social isolation and stress for dogs in the shelter. In doing so, the authors discovered that short (20-minute), repeated interaction sessions with humans across several weeks helped to significantly decrease dogs' salivary cortisol levels, compared to dogs that were not experiencing human-social interaction. At the same time, the results revealed significant increases in some HRV patterns, indicating movement towards higher HRV, demonstrating increased parasympathetic activity and a more regulated physiological state overall. This study revealed a connection between HRV and cortisol levels in dogs; as cortisol levels decrease over time, HRV patterns increase, indicating improved overall welfare for the dog (Bergamasco et al., 2010).

As part of dogs' natural stress response, cortisol, pulse, and respiration rates increase to prepare the body for action (de Carvahlo et al., 2020) while heart rate variability decreases as cortisol levels increase (Bergamasco et al., 2010). In total, pulse, respiration, and HRV can be utilized as practical measures of canine welfare, as they can be continuously collected across time, increasing our overall sensitivity and appreciation about dogs' stress response.

1.4 Activity as an Indicator of Welfare in Shelter-Living Dogs

The activity levels of dogs, characterized both by the duration and frequency of periods of activity and rest, are emerging as promising indicators of canine welfare. Longer periods of prolonged high activity and reduced periods of rest may be indicative of higher stress levels in dogs (Gunter et al., 2021). Additionally, prolonged levels of high activity are positively correlated with both salivary and urinary cortisol levels (Jones et al., 2014).

The level of activity that a dog engages in throughout the day can improve our understanding of their welfare. One method of measuring activity is through the use of accelerometers (Yashari et al., 2015). Accelerometers are sensors attached to a dog's collar or a harness, making contact with their body, usually on the dog's neck, chest, or upper back (Kumpulainen et al., 2021). In order to capture the full range of dogs' movement, accelerometers use triaxial measures, capturing the dog's movement along three axes: vertical (up and down), horizontal (backwards and forwards), and sideways (left to right). The dog's movement is captured at a high frequency to create a detailed understanding of changes in movement across time (Bolton et al., 2021).

1.5 Differences in Activity Levels of Shelter-Living and Home-Housed Dogs

Previous studies investigating dogs' experiences in the shelter and in their adoptive homes indicate that these differing environments affect dogs' activity. Previously, Hoffman and colleagues (2019) measured differences in the activity patterns of 19 shelter-living dogs and 19 home-housed dogs, using tri-axial collar accelerometers. The authors found that shelter dogs have higher activity in the early morning than owned dogs and were most active into the early evening, while owned dogs had the greatest activity in the later evening. It is possible that these changes in activity patterns may be related to environmental differences and their influence on dogs' behavior.

Nocturnal activity (measured through nighttime activity duration and number of bouts of rest) and resting levels, in particular, have been previously studied and may provide us insight into a dog's welfare while living in the shelter. Owczarczak-Garstecka and Burman (2016) studied the sleeping behavior of 15 shelter-living dogs across five non-consecutive days in the shelter by video recording with night-vision cameras. The authors found that dogs sleep for only 3% of their day while living in the shelter, while home-housed dogs can spend up to half of their days asleep (Shade, 2025).

Van der Laan et al. (2023a) further explored changes in nocturnal activity, measured using tri-axial accelerometers with 31 shelter-living dogs in their first four nights in the animal shelter as well as their first four nights in an adoptive home. A control sample of 21 home-housed dogs was additionally measured for their nocturnal activity. The authors also measured dogs' urinary cortisol:creatinine ratios on the mornings of day 1, 2, 3, 7, and 12 in the shelter and home as well as six weeks post-adoption, to further understand dogs' physiological stress in both environments. Body weight was measured on days 1 and 12 in both environments, as well as 6 weeks post-adoption. In all, the goals of this study were to better understand how quality of rest and stress changes as a dog spends time in both the shelter and home environments.

In their study, Van der Laan (2023a) discovered that shelter-living dogs had significantly higher urinary cortisol levels and nocturnal activity than home-housed dogs. Additionally, urinary cortisol levels and nocturnal activity decreased across days spent in the shelter, highlighting likely adaptation over days living in the shelter environment. However, these levels consistently remained higher than those observed in home-housed dogs, indicating reduced welfare for shelter-living dogs, even after an acclimation period. After placement in a home, dogs displayed significantly lower urinary cortisol and nocturnal activity levels, suggesting that dogs experienced greater quality of rest and enhanced welfare following adoption.

In a follow-up study, Van der Laan and colleagues (2023b) also utilized tri-axial collar accelerometers to better understand the differences in nocturnal activity, specifically as dogs acclimate to the shelter environment. To do this, they measured the nocturnal activity of 55 shelter-living dogs across their first 12 nights in the shelter to nocturnal activity of a control group of 21 home-housed dogs. Urinary:cortisol creatinine ratios were collected on day 1, 2, 3, 7, and 12 for shelter-living dogs, as well as on days 1 and 12 of the study for home-housed dogs. They found that dogs in the shelter had significantly higher nocturnal activity and urinary cortisol levels across all days as well as more disrupted rest when compared to home-housed dogs. Moreover, dogs' nocturnal activity was highest in their first two nights in the shelter, decreasing around the twelfth night as the dogs were likely beginning to adapt to their environment; however, nocturnal activity was still higher overall than in owned dogs (Van der Laan et al., 2023b).

Another study by Van der Laan and colleagues (2021) explored changes in dogs' urinary cortisol levels and nocturnal activity across the first 12 nights in a shelter and six months post-adoption. Dogs experienced the highest levels of nocturnal activity during their first two nights in the shelter, as well as highest cortisol levels on the first few days post-intake to the shelter. Nocturnal activity remained similarly high during the first two nights in the shelter, without a significant decrease in activity between night one and night two. Nighttime activity eventually decreased across a 12-day habituation period to the shelter (Van der Laan et al., 2021). In Van der Laan et al.'s (2023a) findings with dogs post-adoption, dogs' nocturnal activity did significantly decrease between the first and second nights in the home. When comparing these two studies, their findings suggest a much faster adaptation period to the home environment compared to the shelter, allowing dogs to experience improved welfare quickly in the home.

To date, only one study has explored differences in the full range of activity between shelter-living and home-housed dogs beyond nocturnal activity levels and rest. In a previously mentioned study by Hoffman et al. (2019), tri-axial accelerometers attached to dogs' collars were used to evaluate differences in activity levels between 19 home-housed and 19 shelter-living dogs across two weeks. The authors found that dogs in shelters spent more time in higher levels of activity overall than dogs living in homes. Shelter dogs also displayed greater consistency with their activity patterns each day compared to dogs in the home. Dogs in the shelter were more active than dogs in the home during the first 75% of the day (12:00 AM - 5:59 PM); dogs in the home were more active than dogs in the shelter during the final 25% of the day (6:00 PM -

11:59 AM). However, even during the five consecutive hours where shelter-living dogs were least active, this population of dogs were still more active than owned dogs were overall.

Given the notable differences in the shelter and home environments, dogs' activity in the shelter may not necessarily correspond to activity once in a home and may instead be indicative of the dog's welfare while being sheltered (Gunter et al., 2019; Van der Laan et al., 2021; Van der Laan et al., 2023a). Most studies exploring changes in activity between shelter-living and home-housed dogs focused primarily on rest and nocturnal activity (Hoffman et al., 2019; van der Laan et al., 2021; 2023a; 2023b). At present, few studies have used a within-subjects design to explore changes to shelter-living dogs' range of activity (i.e., from high activity to rest) before and after placement into a home as an indication of a change in welfare (e.g., cf. Gunter et al., 2019, Gunter et al., 2026). To date, none have involved a duration longer than a few days.

1.6 Influences of Shelter Dogs' Behavior on Staff Perceptions

The shelter and its myriad of stressors can significantly alter dogs' behavior as observed through stereotypic behaviors like pacing and circling as well as excessive panting and vocalizations (Protopopova, 2016). Additionally, longer stays can increase dogs' exposure to these environmental stressors and contribute to chronic stress, further influencing their behavior (Wells et al., 2002b). Particularly, the shelter can influence the presentation of aggressive behavior towards people and other dogs, such that these behaviors are not observed, or to a lesser degree, in the home (Marder et al., 2013; Patronek & Bradley, 2016). Moreover, the outcomes of behavioral evaluations, which often include scenarios that may elicit aggressive behavior, can negatively impact dogs' length of stay and adoption outcomes (Gilchrist, 2024); however, a dog's behavior in the shelter or a previous home may not be representative of what a future adopter will experience in a different home (Duffy et al., 2014).

It is also not uncommon in animal shelters for staff to describe dogs using behavioral labels such as “high-energy” or “active.” However, it is possible that these labels might be misinterpretations of dogs’ behavior when they are experiencing poor welfare and not descriptive of activity needs that should be expected in a home (Jones et al., 2014). In a study by Walker et al. (2016), the Quantitative Behavior Assessment was used to compare the behaviors of dogs in the shelter and home environments. Overall, they found dogs were more likely to be described as “relaxed” or “content” in a home environment than in a shelter. Furthermore, a dog’s length of stay impacted their assessment and the way they were labeled by shelter staff over time. Dogs that were housed in the shelter’s short-term confinement were more likely to be described as “cautious” while dogs in long-term confinement evaluated as “inquisitive.”

A common perspective among animal behaviorists is that no behavioral assessment of a dog in such a stressful, atypical environment, like the shelter, could be completely predictive of their later behavior in a home (Valsecchi et al., 2011). By placing dogs into an environment with reduced stressors, like a foster home, shelter staff can often gather more useful information about a dog’s behavior for potential adopters, including their activity patterns (ASPCA, 2025b). The improved utility of behavioral observations gathered in a home may explain why potential adopters are more likely to use information provided by foster caregivers when making adoption decisions about dogs than information provided by shelter staff (Mohan-Gibbons et al., 2014).

1.7 Utilizing the Shelter C-BARQ to Evaluate Behavior

The Canine Behavioral Assessment and Research Questionnaire (C-BARQ) is a 100-item questionnaire developed to help owners and canine professionals more accurately describe dogs’ behavior, including their responses to other dogs and people, in everyday contexts (i.e., entering the home or on walks with the owner; Hsu & Serpell, 2003). The C-BARQ has been used in many contexts, including to evaluate breed differences in behavior (van den Berg et al., 2010), predicting successful behaviors in working dogs (Hare et al., 2024), selection of dogs for animal therapy (Sakurama et al., 2023), and evaluating behavioral concerns in home-housed dogs (Hsu & Sun, 2010).

In a recent study by Bohland et al. (2023), the researchers utilized the C-BARQ to further understand dogs' behavior in the home following adoption from an animal shelter. As time passed in the adoptive home, they found that behaviors like aggression, fear, excitability, and anxiety-related behaviors emerged or intensified while separation-anxiety related behaviors, attachment concerns, and attention-seeking behaviors decreased. The results of this study suggest that dogs' behavior following adoption may change over time and may not be comparable to behavior evaluated when the dog leaves the shelter for adoption.

The C-BARQ, which is designed to help owners accurately evaluate and describe their dog's behavior (Hsu & Serpell, 2003), was deployed with over 400 staff and volunteers about dogs living in 11 US shelters by Gilchrist et al. (2025). Afterwards, Gilchrist et al. (2025) developed the 24-item Shelter C-BARQ to improve the accuracy of behavioral assessments in shelters and create a more predictive picture of shelter dogs' behavior in context to their environment. The goal of the Shelter C-BARQ was to help shelter staff accurately describe the behavior of dogs in their care, while also providing a representation of dogs' behavior in typical shelter contexts, including in the kennel. This survey allows individuals to evaluate a dog's fear, arousal, human excitability, human and dog aggression specifically in the context of the shelter environment to gather more information about a dog's behavior.

Despite these prior findings, no published study has utilized the C-BARQ or Shelter C-BARQ questionnaire to understand similarities between dogs' behaviors in both the shelter and adoptive home. Additionally, no study has explored how a dog's activity might align with their behavior between environments, how activity itself might be influenced by their environment, or how the perceptions of dogs' activity and behavior align with actual accelerometer measurements. This is an important gap that is directly addressed in the current study.

1.8 Exploring Novel Connections Between Physiological Welfare, Activity, and Environment

The existing scientific literature has not compared dogs' multiple physiological measures of welfare, in the form of pulse, respiration, heart rate variability, and activity, across multiple days in both shelter and home environments using a within-subjects design. Considering their links with cortisol, heart rate variability, respiration, and pulse can be utilized to more fully understand dogs' stress response in the shelter. Meanwhile, these physiological measures can be collected more quickly, efficiently, and consistently across multiple days through a continuously-worn health-monitoring collar. Continuous monitoring allows researchers to capture changes that might not be detected through timepoint collection of biological samples for cortisol or other hormonal analysis.

Our study aims are to: (1) investigate the relationship between a dog's environment and welfare through their activity and physiological indicators (e.g., pulse and respiration rates, heart rate variability, and activity), (2) determine if and how physiological welfare and activity changes over time in each environment, and (3) examine the differences in perceptions of dogs' behavior and activity between the shelter and home environments. To fill these gaps in the scientific literature, we utilized health-monitoring collars to collect dogs' physiological and activity data during their last 20 days in a kenneling environment before placement into a home and their first 20 days in a home. These findings aim to provide a better understanding of dogs' activity and behavior changes as they transition across environments, such that sheltering organizations may better appreciate dogs' welfare, understand differences in dogs' behavior, and recognize biases in their behavioral perceptions. In addition, the findings can also aid staff in counseling prospective adopters to align expectations of adoptive families and foster caregivers once dogs are placed into a home.

2.0 Method

2.1 Participants

Three cohorts of dogs participated in this study, the first consisting of eight dogs and the final two consisting of seven dogs (n = 22). Participating dogs were housed in dog kennels (145 centimeters wide by 211 centimeters long) at the Virginia-Maryland College of Veterinary Medicine (VMCVM) for four to six weeks before placement into a home (i.e., adoptive or foster). Adult dogs (over six months) were selected based on sociability with people and other dogs, determined by evaluations from canine behaviorists. All dogs were clinically evaluated at the Virginia-Maryland College of Veterinary Medicine and determined to be in good health prior to beginning the study. Each dog was over the age of six months and under the age of nine years. Previously, these adult dogs residing at a municipal animal shelter in Roanoke, Virginia awaiting adoption.

The VMCVM was utilized as a traditional shelter environment in which participating dogs were singly housed in kennels while they awaited adoption. However, dogs were participating in a Shelter Dog Training course through the School of Animal Sciences at Virginia Tech in which teams of undergraduate students taught dogs basic training skills using positive reinforcement techniques and assisted in their home placements. During their time in the course, dogs received more outings and social interaction than is common at most shelters. Dogs typically received six outings a day with students or staff, such as a walk, training or interaction session, and attending thrice weekly hands-on training and enrichment classes with faculty and students. They also participated in a research study evaluating the use of automated feeders in the reduction of barking in kennels. Dogs were available for adoption, and potential adopters and foster caregivers met dogs with members of their families, including dogs, before placement. Following the graduation of a course's cohort, dogs were placed in homes in southwest Virginia.

2.2 *Materials*

2.2.1 Health Monitoring Collar Apparatus

At the VMCVM and during the dogs' first three weeks in their adoptive or foster home, dogs wore PetPace Health 2.0 collars. PetPace health monitoring collars consist of four measurement apparati: thermometers, acoustic sensors, 6-D accelerometers, and Global Positioning System (GPS) trackers. Six-D accelerometers measure changes in activity levels using an algorithm that translates vectors (m/s^2) every minute into a calculated activity level on a scale of 0 to 100, where 0 represents no movement at all for one minute and 100 is the maximum possible activity for one minute. Dogs' activity was measured each minute using an accelerometer; activity levels were summed for each 24-hour period and categorized from 1-100 as either resting (0-24), low (25-21), medium (32-47), or high (>48) activity. Previous studies have found PetPace collars to be reliable measures of dogs' activity when compared to Actical monitors (Belda et al., 2018; Rowlison de Ortiz et al., 2022). Thermometers within the PetPace collar detect temperature and fevers. Dogs' locations are tracked through GPS sensors.

Acoustic sensors within the collars were utilized to capture pulse and heart rate variability every minute, and respiration rates through vibrations at the base of the throat every two minutes. Rubber acoustic concentrators within the collar contact the base of the dog's neck, penetrating fur to make necessary contact with the dog's skin. A microelectromechanical system

(MEMS) microphone in the acoustic sensor detects the low-frequency acoustic signals created by contractions of the heart and pulse waves through arteries. The sound waves from these internal functions are converted into electrical signals within the collar. Proprietary PetPace algorithms filter out extraneous noise (e.g., sounds from panting, barking, or movement) and isolate the specific signals to determine pulse and respiration rates.

After the pulse has been detected, the vasovagal tonus index (VVTI) is used to calculate heart rate variability. VVTI is calculated from the logarithm of the standard deviation of time between consecutive heart beats (R - R intervals), using the formula $VVTI = \log_e(sd_{R\text{-}R})^2$. In this formula, *log* is logarithm and *sd* is the standard deviation of consecutive R-R intervals in a one-minute period. One VVTI calculation alone can be used to measure short-term heart rate variability over a one-minute period, but measurement of VVTI over time can help provide a greater understanding of the change in heart rate variability for dogs across time. For the purposes of this study, VVTI will be referred to as heart rate variability (HRV).

Participating dogs were fitted for a collar within their first 48 hours in the VMCVM kennels. Dogs were fitted for a large, medium, or small collar based on individual fitting of the collar (i.e., if a large-sized collar allowed more than two fingers of space between the collar strap and the base of the neck, a smaller sized collar was used). Collars were tightened such that two fingers could fit between the collar strap and the base of the neck to ensure that the collars are comfortable for the dogs and able to collect required data.

During the duration of the study, dogs wore their PetPace collar, which was replaced with another PetPace collar whenever the battery reached a low level (~5%). Collars were charged and typically replaced 48 hours later upon completion of charging with times of collar changes recorded to ensure data integrity for each dog. Dogs continued to wear their collars when leaving

VMCVM for placement into a home. Within 72 hours in the home, first author (GP) connected dogs' collars to the adopter or caregiver's home WiFi network to maintain battery life. As needed due to battery and connectivity needs, collars were replaced.

2.2.2 Behavior & Activity Questionnaire

After each dog was living at the VMCVM for approximately three weeks (between days 20 and 25) colony care staff were sent a behavior and activity questionnaire to complete. This included 1) the Shelter Canine Behavior and Research Questionnaire (Shelter C-BARQ) regarding their observations of the dog's behavior, 2) description of the dog's activity levels, and 3) perceived time the dog spent in rest, light to moderate, and high activity. A staff member that was knowledgeable about the dog completed its questionnaire. Typically, staff members completed questionnaires for 1-2 dogs per cohort. Adopters and foster caregivers also completed the behavior and activity questionnaire after their dog resided in their home for three weeks. Shelter C-BARQ questions that used words, such as kennel, were returned to the phrasing that was used in the C-BARQs (i.e., home; Duffy et al., 2014).

When completing the behavior and activity questionnaire, care staff caregivers were asked to rate the dog's tendency to display fear (e.g., "When an unfamiliar person tries to touch or pet the dog") on a Likert scale ranging from (1) "no fear" to (5) "extreme fear." Similarly, questions about the dog's arousal (e.g., "Chews inappropriate objects") were also rated on a Likert scale of (1) "never" to (5) "always." Questions about the dog's excitability (e.g., "Playing with you or someone else") were rated from (1) "calm" to (5) "extremely excitable," and the dog's aggressive behavior towards humans and dogs (e.g., "Towards unfamiliar persons visiting your home") was rated on a Likert scale of (1) "no stress" to (5) "serious stress." Higher total scores within each factor indicate greater levels of fear, arousal, excitability, or aggression.

In order to facilitate description of a dog's activity level, staff were provided labels of increasing levels of activity (low to high): couch potato, neighborhood stroller, power walker, hiking partner, and running buddy. A final question asked staff to indicate what percentage of the day they thought the dog engaged in rest, light to moderate, and high activity (which summed to 100%).

2.3 Statistical Analysis

Pulse, respiration rate, HRV, and activity data were derived from values reported from PetPace without any alterations to these data. Data collected from both collars that a single dog wore in each environment were exported and combined into a dog's single dataset. These single datasets were then combined with datasets of all other dogs and analyzed using Stata 18.0 statistical software. To standardize the study's data prior to analysis in an effort to avoid overrepresentation of dogs that contributed more days of data than others, data was limited to the activity and physiological data of dogs 20 days in the shelter prior to home placement and 20 days following. Any data prior to the last 20 days in the shelter and the first 20 days in the home were excluded.

A generalized linear model with a binomial distribution was used to examine whether dogs' activity changed by level (i.e., rest, low, medium, or high), environment (i.e., shelter or home), or in a level-by-environment interaction. In this model, dog ID was included as a random effect, and level, environment, and their interaction included as fixed effects. Model fit was determined by log likelihood, the smallest Bayesian Information Criterion (BIC). A negative binomial model was used to examine whether dogs' activity changed across time spent in each environment.

Separate mixed-effects REML regressions were used for each type to determine the effect of environment (i.e., shelter or home) on dogs' physiological welfare indicators (i.e., pulse, respiration, and heart rate variability). In this model, dog ID was included as a random effect, and pulse, respiration, heart rate variability, and environment were included as fixed effects. Model fit was determined by log likelihood, the smallest Bayesian Information Criterion (BIC).

Linear regression models were used to analyze differences in the arousal behavior question scores provided by care staff while dogs were living in the shelter and those provided by owner/caregivers in the home. Linear regression models were also used to understand differences in perceptions of the amount of time dogs spent in resting, low to medium, and high activity between the shelter and the home. Additionally, Mann-Whitney U tests were used to compare changes in dogs' fear, excitability, human aggression, dog aggression, and perceived activity level between the scores provided by the care staff in the shelter and owners/caregivers in the home. Wilcoxon signed-rank tests were used to explore changes in the proportion of time that dogs spent at each activity level between environments.

2.4 Ethics Approval

Procedures were approved by the Virginia Tech Institutional Animal Care and Use Committee (IACUC: 22-210). The behavior and activity questionnaire was approved by the Virginia Tech Institutional Review Board (IRB: 24-126).

3.0 Results

3.1 Descriptive Statistics

A total of 22 dogs housed at the VMCVM and in homes participated in the study. One dog was adopted out of the area of the university and did not wear the collar in their adoptive home. Another dog was returned to the originating shelter prior to home placement due to behavioral concerns, and an additional dog's home environment did not allow for collar connection via WiFI. As such, the total number of dogs represented in these data is 19. On average, dogs were approximately two years old (*M* = 23.57 months; *SD* = 23.03) and weighed about 20 kg (*M* = 19.84; *SD* = 7.78). Female dogs represented 47% of the sample (53% male).

3.2 Physiological Measurements

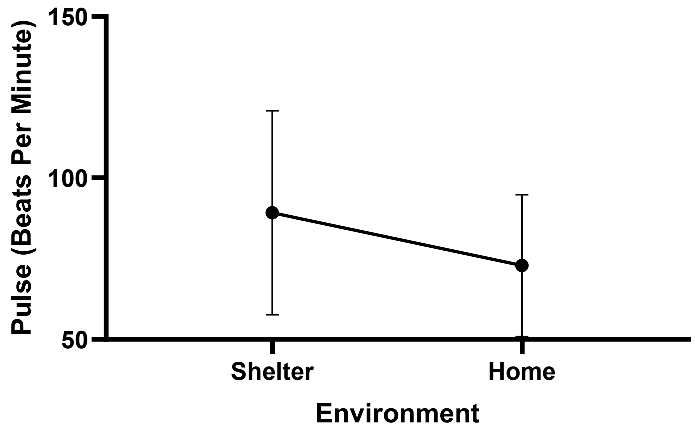
PetPace collars worn by the dogs generated 51,859 respiration rate readings and 81,305 pulse and HRV readings across shelter and home environments that were statistically analyzed using mixed-effects REML regression models.

3.2.1 Pulse

Our model indicated a significant main effect of environment on dogs' pulse, $\chi2(3) = 2168.66$, $p < 0.001$, such that dogs in the home environment have a significantly lower baseline pulse than dogs in the shelter (about 2 bpm lower) and pulse rates were 16 bpm higher overall on average in the shelter than in the home ($\beta = -1.997$, $SE = 0.346$, $z = -5.78$, 95% CI [-2.67, -1.32], $p < .01$; Figure 1).

Figure 1

Average pulse rate of dogs in the animal shelter and home

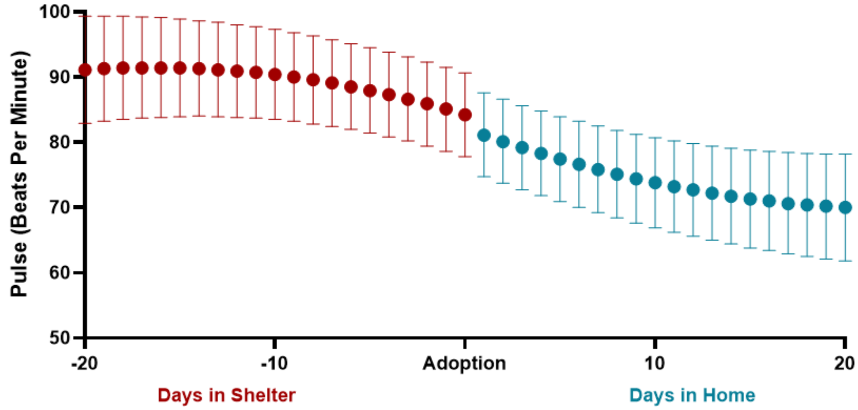


Note. The model indicates a significant difference in average pulse rates between the shelter and the home. Bars represent standard deviation.

Additionally, dogs' average pulse per day initially decreased at a faster rate in the home than in the shelter (β = -0.181, *SE* = 0.054, *z* = -3.32, 95% CI [-0.289, -0.074], *p* = .01) with the rate of decrease reaching stable levels more quickly in the home than in the shelter (β = 0.050, *SE* = 0.002, *z* = 22.20, 95% CI [0.046, 0.054], *p* < .01; Figure 2). Ten days prior to leaving the shelter, the average pulse rate across dogs in the study was 90.7 beats per minute. The day before leaving the shelter for adoption or foster, dogs' average pulse rate was 85.9 beats per minute. Once in the home for 10 days, dogs' pulse rate decreased to 74.4 beats per minute.

Figure 2

Model-predicted pulse trajectories across 20 days in the shelter and home



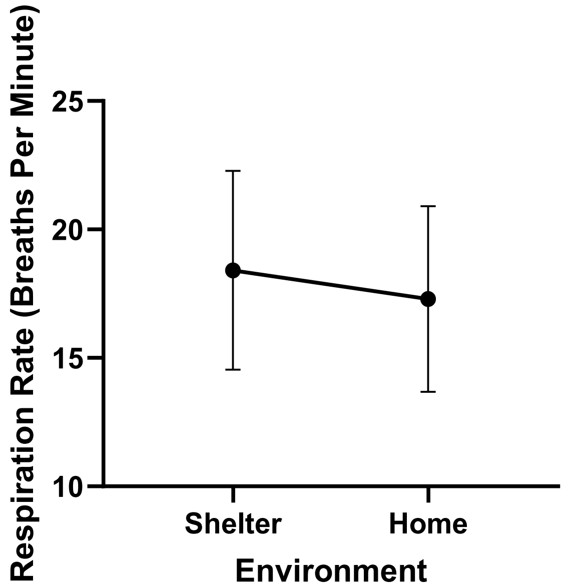
Note. The model indicates that pulse declined more rapidly after entering the home (blue) and reached a stable level earlier compared to the shelter (red). Bars represent 95% confidence intervals.

3.2.2 Respiration

Our model indicated a significant main effect of the environment on dogs' respiration rate, $\chi 2(3) = 254.26$, $p < 0.001$. Dogs' baseline respiration was significantly lower (~0.4 breaths per minute) in the home than the baseline respiration rate in the shelter, as well as 1 breath per minute lower on average overall in the home than in the shelter ($\beta = -0.388$, $SE = 0.072$, $z = -5.42$, 95% CI [-0.528, -0.248], $p < .01$; Figure 3).

Figure 3

Average respiration rate of dogs in the animal shelter and home

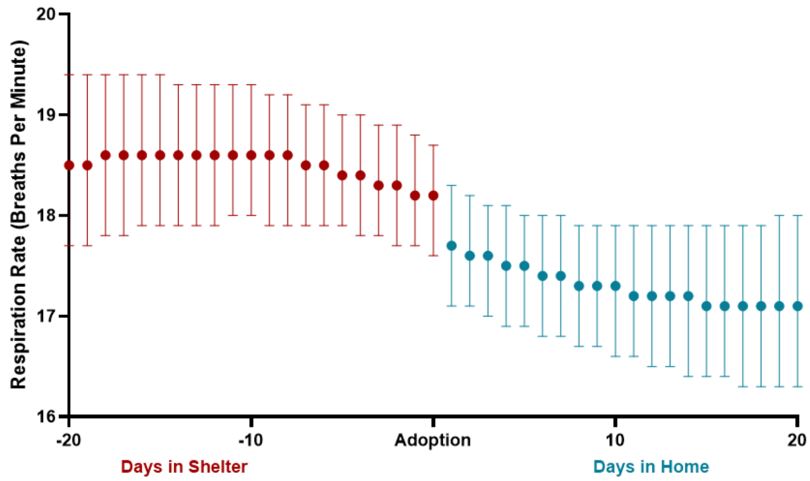


Note. The model indicates a significant difference in average respiration rates between the shelter and the home. Bars represent standard deviation.

Ten days prior to leaving the shelter, the average respiration rate across dogs was 18.6 breaths per minute. The day before leaving the shelter, the respiration rate was 18.3 breaths per minute. The average respiration rate decreased to 17.3 breaths per minute 10 days after entering the home. There was no significant difference in the rate of change between dogs' respiration rates in the shelter and home over time (Figure 4).

Figure 4

Model-predicted respiration trajectories across 20 days in the shelter and home



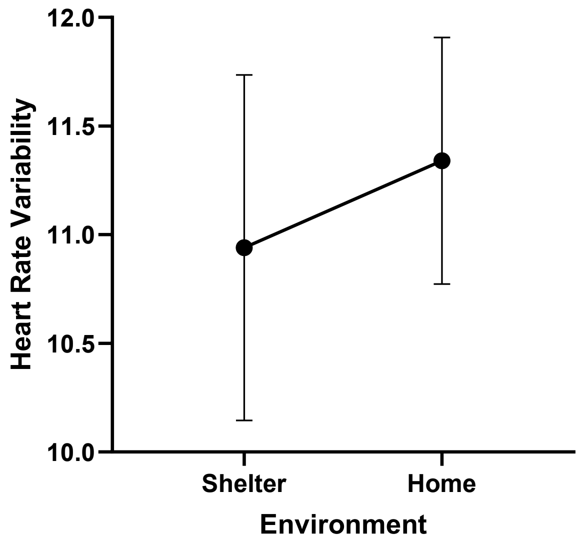
Note. The model indicates no difference in respiration rates between the home (blue) and the shelter (red). Bars represent 95% confidence intervals.

3.2.3 Heart Rate Variability

A mixed-effects REML regression indicated a significant main effect of the environment on dogs' heart rate variability, $\chi 2(3) = 2290.39$, $p < 0.001$. The analysis revealed dogs' baseline heart rate variability was significantly higher (~0.2) in the home than in the shelter, as well as 0.4 higher overall on average in the home than in the shelter ($\beta = 0.119$, $SE = 0.009$, $z = 13.08$, 95% CI [0.101, 0.137], $p < .01$; Figure 5).

Figure 5

Average heart rate variability of dogs in the animal shelter and home

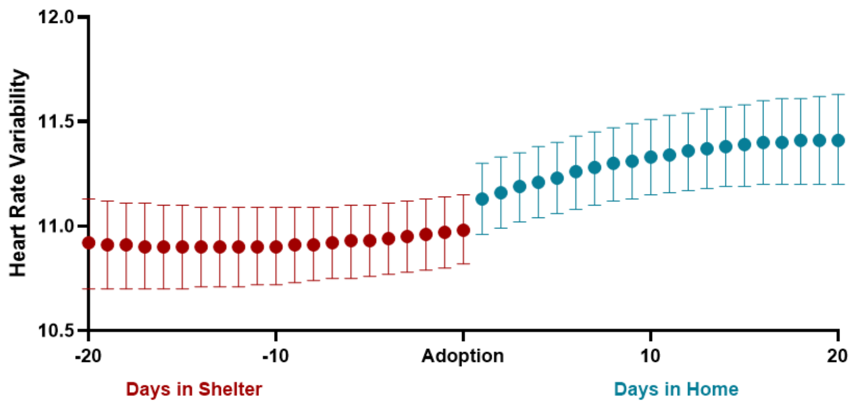


Note. The model indicates a significant difference in average heart rate variability between the shelter and the home. Bars represent standard deviation.

Overall, heart rate variability initially increased at a faster rate in the home than in the shelter (β = 0.017, *SE* = 0.001, *z* = 11.85, 95% CI [0.014, 0.020], $p < .01$). However, the rate of increase in heart rate variability reached stable levels faster over time in the home than in the shelter (β = -0.001, *SE* < 0.001, *z* = -19.61, 95% CI [-0.001, -0.001], $p < .01$). At 10 days before leaving the shelter, dogs' average heart rate variability was 10.90. The day before leaving the shelter, dogs' heart rate variability was 10.97. After 10 days in the home, heart rate variability increased to 11.33 (Figure 6).

Figure 6

Model-predicted heart rate variability trajectories across 20 days in the shelter and home



Note. The model indicates that HRV increased faster after entering the home (blue) and reached a stable level earlier compared to the shelter (red). Bars represent 95% confidence intervals.

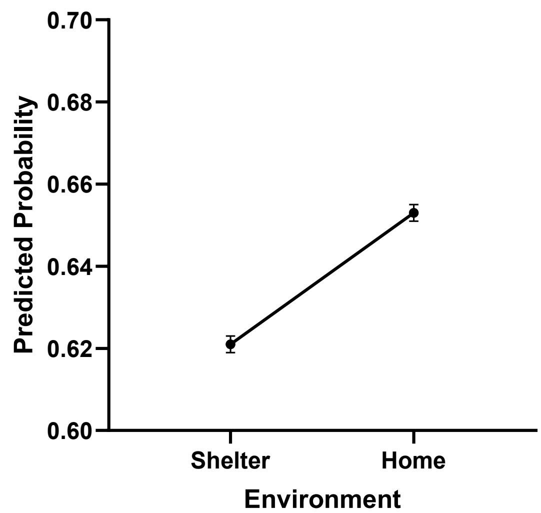
3.3 Activity

Dogs in our study generated 1,576 activity values, categorized by rest, low, medium, and high activity, that were statistically analyzed using a generalized linear model. A mixed-effects REML regression was used to detect an effect of weight, age, and sex on activity levels.

The analysis indicated a significant interaction between the dog's environment and the types of activity they engaged in, $\chi 2(3) = 28.65$, $p < 0.001$, as well as main effects of environment and activity type ($p < .001$). Post hoc contrast comparisons of the interaction revealed a significant difference in the probability of time dogs spent resting (contrast estimate = 0.032, 95% CI [0.029, 0.035], $p < 0.001$) and in medium activity (contrast estimate = 0.015, 95% CI [0.013, 0.018], $p < 0.001$) in a home as compared to the shelter, such that dogs had a greater probability of rest and medium activity while in the home (Figures 7 and 8, respectively).

Figure 7

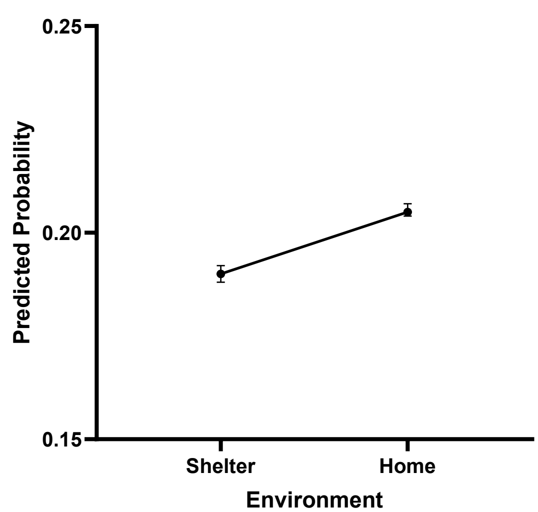
Predicted probabilities of time spent at rest in the shelter and home



Note. The model indicates a significant difference in the predicted probability of rest between the shelter and the home. Bars represent 95% confidence intervals.

Figure 8

Predicted probabilities of time spent in medium activity in the shelter and home

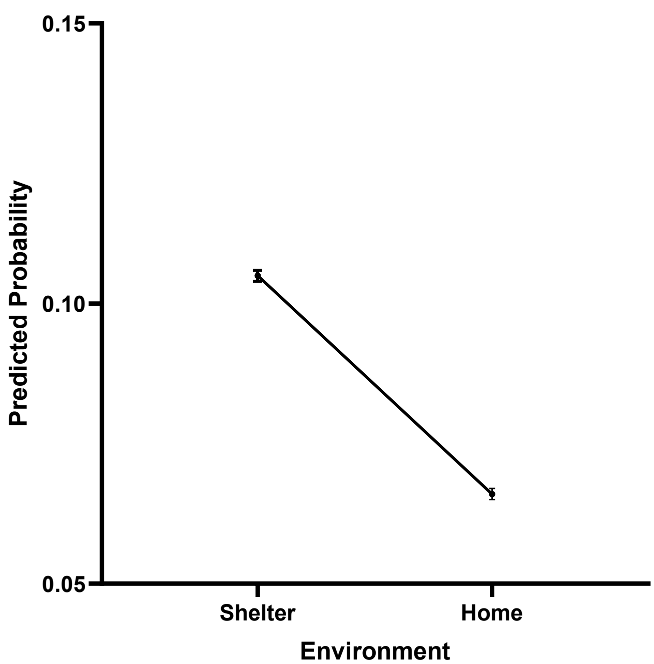


Note. The model indicates a significant difference in the predicted probability of medium activity between the shelter and the home. Bars represent 95% confidence intervals.

Post hoc contrast comparisons of the interaction revealed a significant difference in the probability of time dogs spent in high activity (contrast estimate = -0.039, 95% CI [-0.041, -0.037], $p < 0.001$) and low activity (contrast estimate = -0.008, 95% CI [-0.010, -0.007], $p < 0.001$) between the environments, indicating that dogs had a greater probability of spending time in high and low activity when living in the shelter versus the home (Figures 9 and 10, respectively).

Figure 9

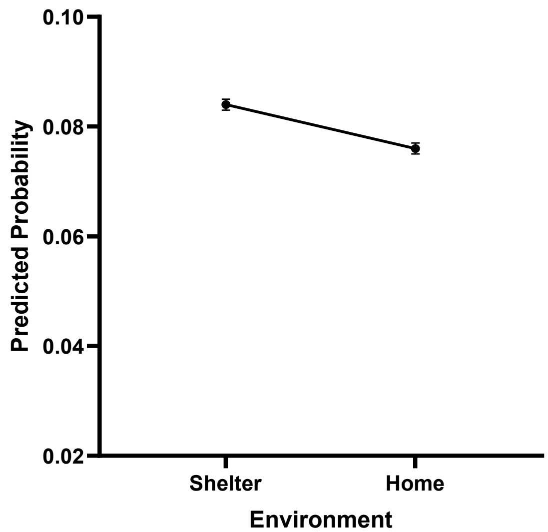
Predicted probabilities of time spent in high activity in the shelter and home



Note. The model indicates a significant difference in the predicted probability of high activity between the shelter and the home. Bars represent 95% confidence intervals.

Figure 10

Predicted probabilities of time spent in low activity in the shelter and home



Note. The model indicates a significant difference in the predicted probability of low activity between the shelter and the home. Bars represent 95% confidence intervals.

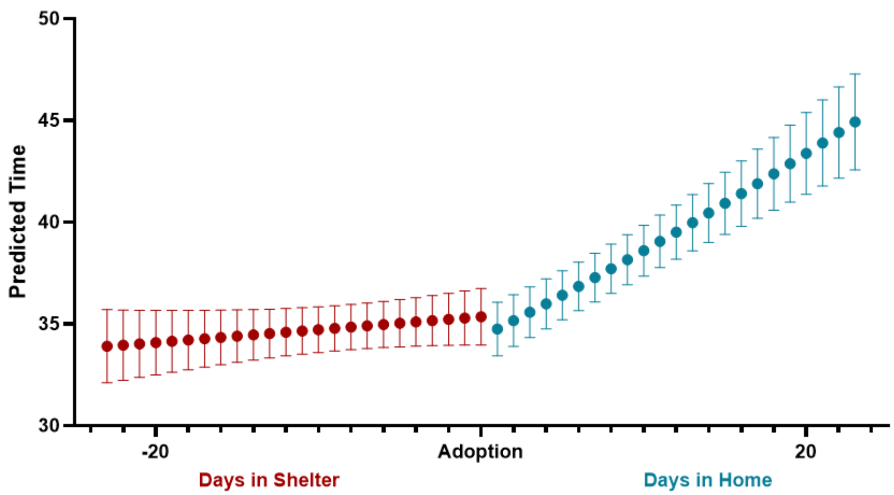
Wilcoxon signed-rank tests were used to explore changes in the proportion of time that dogs spent at each activity level (rest, low, medium, and high) between the shelter and the home. Proportionally, dogs spent significantly more time at rest in the home (63.4%) than in the shelter (58.5%), $z = -2.800$, $p = 0.005$. The test also revealed that dogs spent proportionally more time in low activity in the shelter (8.3%) versus the home (7.5%), $z = -2.203$, $p = 0.028$, and more time in high activity in the shelter (12.4%) than in the home (7.2%), $z = -3.584$, $p < 0.001$. There was no significant difference in the proportion of time spent in moderate activity between the shelter and home environments.

No statistical difference was found in the amount of time dogs spent resting in adoptive versus foster homes ($p = 0.269$). There were no significant effects of weight ($p = 0.103$) or age, weight, or sex ($p = 1.00$) on time spent resting in either environment.

Using separate generalized linear mixed models with negative binomial distributions, we found significant differences in the rates of rest ($\chi 2(3) = 5.31$, $p = 0.021$), low ($\chi 2(3) = 5.59$, $p = 0.018$), medium ($\chi 2(3) = 5.72$, $p = 0.017$), and high ($\chi 2(3) = 12.39$, $p < 0.001$) activity across the 20 days in each environment. Rate of rest significantly increased only in the home environment by 1.2% each day (IRR = 1.012, 95% CI [1.006, 1.017], $p < 0.001$; Figure 11). Rate of rest did not significantly change in the shelter (IRR = 1.002, 95% CI [0.996, 1.007], $p = 0.520$). Rate of low activity significantly decreased only in the home environment by 0.8% each day (IRR = 0.992, 95% CI [0.986, 0.999], $p = 0.017$; Figure 12). Rate of low activity did not significantly change in the shelter (IRR = 1.004, 95% CI [0.997, 1.011], $p = 0.232$).

Figure 11

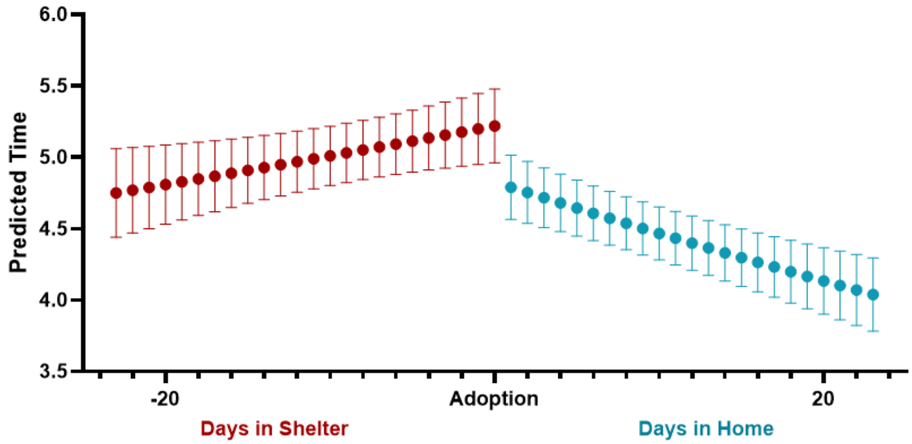
Model-predicted rest trajectories across 20 days in the shelter and home



Note. The model indicates that rest increased rapidly after entering the home (blue), but did not change across time spent in the shelter (red). Bars represent the 95% confidence intervals.

Figure 12

Model-predicted low activity trajectories across 20 days in the shelter and home

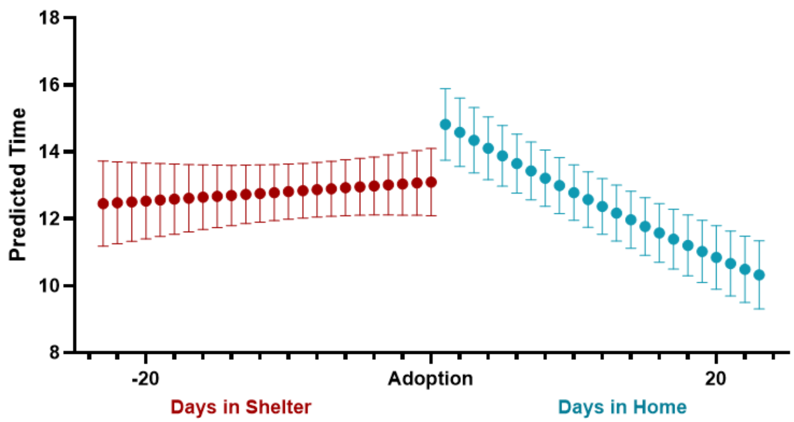


Note. The model indicates that low activity decreased after entering the home (blue), but did not significantly change in the shelter (red). Bars represent the 95% confidence intervals.

Meanwhile, the rate of medium activity significantly decreased by 1.6% each day only in the home (IRR = 0.984, 95% CI [0.974, 0.993], $p = 0.001$; Figure 13). Rate of high activity significantly decreased by 1.8% in the shelter (IRR = 0.982, 95% CI [0.967, 0.996], $p = 0.014$) and 5.6% each day in the home (IRR = 0.944, 95% CI [0.931, 0.957], $p < 0.001$; Figure 14).

Figure 13

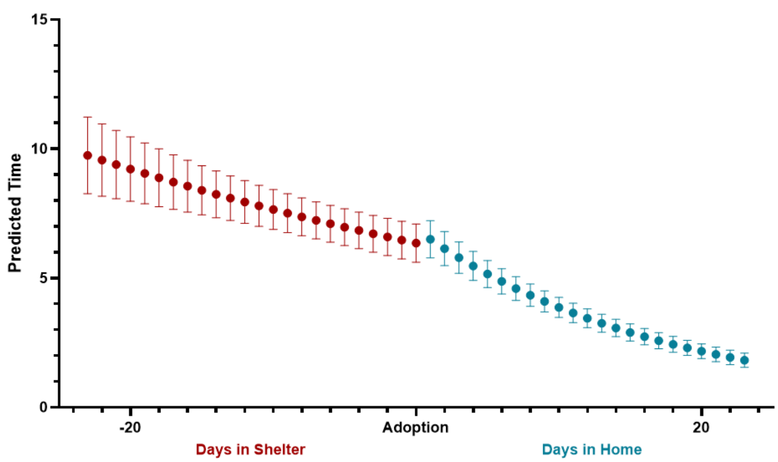
Model-predicted medium activity trajectories across 20 days in the shelter and home



Note. The model indicates that medium activity decreased after entering the home (blue), but did not change across time spent in the shelter (red). Bars represent the 95% confidence intervals.

Figure 14

Model-predicted high activity trajectories across 20 days in the shelter and home



Note. The model indicates that high activity decreased more rapidly after entering the home (blue) compared to the shelter (red), but time spent in high activity also decreased across time in the shelter. Bars represent the 95% confidence intervals.

3.4 Behavior and Activity Questionnaire

3.4.1 C-BARQ: Fear

Mann-Whitney U tests revealed a significant difference in dogs' behavior "when barked, growled, or lunged at by an unfamiliar dog when being walked on-leash" between the shelter and the home, $U = 91.00$, $z = -2.576$, $p = 0.01$, such that owners and caregivers rated dog's fearful behavior higher when barked at or growled at by an unfamiliar dog on leash than shelter care staff.

A significant difference between environments was also found in C-BARQ ratings of dogs' behavior when exposed to unfamiliar situations or entering the kennel (or home) for the first time, $U = 93.50$, $z = -2.333$, $p = 0.020$. Owners and caregivers in the home rated their dog's fearful behavior higher when approached by an unfamiliar dog than shelter care staff. The test revealed a significant difference in dogs' responses to sudden or loud noises between the shelter and home, $U = 81.00$, $z = -2.744$, $p = 0.006$, such that owners and caregivers in the home rated their dog's fearful behavior higher in response to sudden loud noises compared to care staff in the shelter. There was a near significant difference in dogs' fearful behavior when approached by an unfamiliar dog on leash or in the home, with owners rating fearful behavior when approached by an unfamiliar dog in the home higher than care staff in the shelter, $U = 100.00$, $z = -2.264$, $p = 0.051$. There was no significant difference between care staff and owner ratings of any of the other four fear-based questions on the C-BARQ (Table 1).

Table 1

Average shelter and home ratings for C-BARQ fear-based questions

Question	Average Shelter Rating	Average Home Rating

1. When an unfamiliar person (to the dog) tries to touch or pet this dog.	1.06	1.28
2. In response to sudden or loud noises (e.g. car backfire, road drills, objects being dropped, etc.).	**1.11**	**2.11**
3. When a familiar person returns to the kennel/home.	1	1
4. In response to strange or unfamiliar objects while on-leash (e.g., plastic trash bags, leaves, litter, flags flapping, etc.).	1.26	1.28
5. When first exposed to unfamiliar situations.	**1**	**1.67**
6. When approached by an unfamiliar dog on leash/in the home.	*1.05*	*0.89*
7. When barked, growled, or lunged at by an unfamiliar dog when being walked on-leash.	**0.37**	**1.11**

Note. Bolded questions: $p < 0.05$. Italicized question: $p = 0.051$.

3.4.2 C-BARQ: Arousal

Mann-Whitney U tests were also used to compare the ratings provided by care staff in the shelter and caregivers in the home on the six C-BARQ arousal questions. There was no significant difference between dogs' arousal-related behaviors in the shelter and in the home, indicating that shelter care staff did not rate dogs' arousal behaviors differently than owners and caregivers.

Table 2

Average shelter and home ratings for C-BARQ arousal-related questions

Question	Average Shelter Rating	Average Home Rating
1. Easily distracted by interesting sights, sounds, and smells.	3.95	3.39
2. Barks or whines when you leave or are about to leave the kennel/home (even momentarily).	2	1.61
3. Chases or wants to chase rabbits, squirrels, or other small animals if given the opportunity.	3.58	3.33
4. Chews or attempts to chew inappropriate objects.	1.79	2.61
5. Pulls on the leash (when walking equipment IS used, such as a harness).	3.52	2.11
6. Attempts to escape or would escape from their kennel or enclosure if given the chance.	2.42	2

3.4.3 C-BARQ: Human Excitability

Mann-Whitney U tests compared C-BARQ scores provided by care staff in the shelter and owners and caregivers in the home about dogs' excitability in four contexts. The only significant difference found was when participants were asked about dogs' excitability during visitor arrivals," $U = 112.50$, $z = -2.157$, $p = 0.031$, such that care staff in the shelter rated dogs' excitability higher with visitors than owners and caregivers in the home.

Table 3

Average shelter and home ratings for C-BARQ human excitability questions

Question	Average Shelter Rating	Average Home Rating
1. When you or others return after a brief absence (including inside the building but away from the dog).	2.21	2.72
2. Playing with you or someone else.	2.21	2.33
3. Just before being taken for a walk.	2.42	2.22
4. When visitors arrive at their kennel/home.	**2.37**	**1.83**

Note. Bolded question: $p < 0.05$.

3.4.4 C-BARQ: Human Aggression

Mann-Whitney U tests were utilized to explore differences in dogs' aggressive behavior toward people, by comparing C-BARQ ratings provided by care staff in the shelter and owners and caregivers in the home in three situations. In only one question, "when an unfamiliar person tries to touch or pet the dog," the Mann-Whitney U test revealed a significant difference between the shelter and the home, $U = 127.50$, $z = -2.002$, $p = 0.045$, such that owners and caregivers rated their dog's aggressive behavior higher in this situation than care staff in the shelter.

Table 4

Average shelter and home ratings for C-BARQ human-directed aggression questions

Question	Average Shelter Rating	Average Home Rating
1. When approached by a new person while being walked on-leash.	1.05	1.22
2. When an unfamiliar person (to the dog) tries to touch or pet the dog.	**0.84**	**1.06**
3. Towards familiar people returning to their kennel/visiting the home.	1	1

Note. Bolded question: $p < 0.05$.

3.4.5 C-BARQ: Dog Aggression

Mann-Whitney U tests revealed significant differences in dogs' behavior when comparing ratings provided by shelter care staff and owners and caregivers in the home on two of the four C-BARQ dog-related aggression questions. Owners and caregivers rated their dogs' dog-aggressive behavior higher "when [their dog] was barked, growled, or lunged at by another (unfamiliar) dog" than care staff in the shelter, $U = 100.50$, $z = -2.277$, $p = 0.023$. Additionally, a significant difference was found between ratings of dogs' aggressive behavior "when approached by another (familiar) dog in your household or when dogs walk past their kennel," $U = 83.50$, $z = -2.805$, $p = 0.005$. Shelter care staff rated this behavior higher for dogs in the shelter than caregivers did in the home.

Table 5

Average shelter and home ratings for dog-directed aggression C-BARQ questions

Question	Average Shelter Rating	Average Home Rating
1. When approached by an unfamiliar dog while being walked on-leash.	0.89	1.06
2. When being barked, growled, or lunged at by another (unfamiliar) dog while being walked on-leash.	**0.37**	**0.89**
3. When dogs walk past their kennel/when approached by another (familiar) dog in your household.	**1.26**	**0.67**
4. When toys, bones, or other objects are taken away.	1	1

Note. Bolded questions: $p < 0.05$.

3.5 Activity Descriptions

A Mann-Whitney U test comparing the descriptive labels of dogs' activity types provided by care staff in the shelter and owners and caregivers in the home were not significantly different, $U = 127.00$, $z = -1.178$, $p = 0.239$.

3.6 Perceived Activity Distribution

A linear regression model was used to compare the effect of the environment on perceptions of the percentage of time each dog spent at rest, in light to moderate activity, and in high activity. No significant model fit was found to compare the effect of environment on reports of rest ($F(1, 34) = 0.014$, $p = 0.906$), light to moderate activity ($F(1, 34) = 0.003$, $p = 0.955$), or high activity ($F(1, 34) = 1.828$, $p = 0.185$). It is worth noting that there were differences in the average percentage of time dogs spent in each activity level, measured through the PetPace collars (using PetPace's low and medium levels for light to moderate activity and PetPace's high level for high activity) and the perceived percentage of time that dogs spent in each activity level in both the shelter and the home, measured through surveying care staff and owners/caregivers.

In the shelter, care staff underreported the amount of time that dogs spent at rest (45.2% reported versus 58.5% measured). Meanwhile, care staff overestimated the amount of time that dogs spent in low to moderate activity (37% reported versus 29.1% measured) and high activity (17.8% reported versus 12.4% measured). In the home, owners and caregivers followed similar trends. They underestimated the amount of time that dogs spend resting in the home, perceiving that dogs spend about 20% less time at rest than what was measured with the PetPace collars. Additionally, owners and caregivers overreported the percentage of time that dogs spend in low to moderate activity (36.5% reported versus 29.4% measured) and high activity (20.2% reported versus 7.2% measured).

Figure 15

Percent time dogs spent in each activity level compared to care staff's perception of percent time dogs spent in each activity level in the shelter

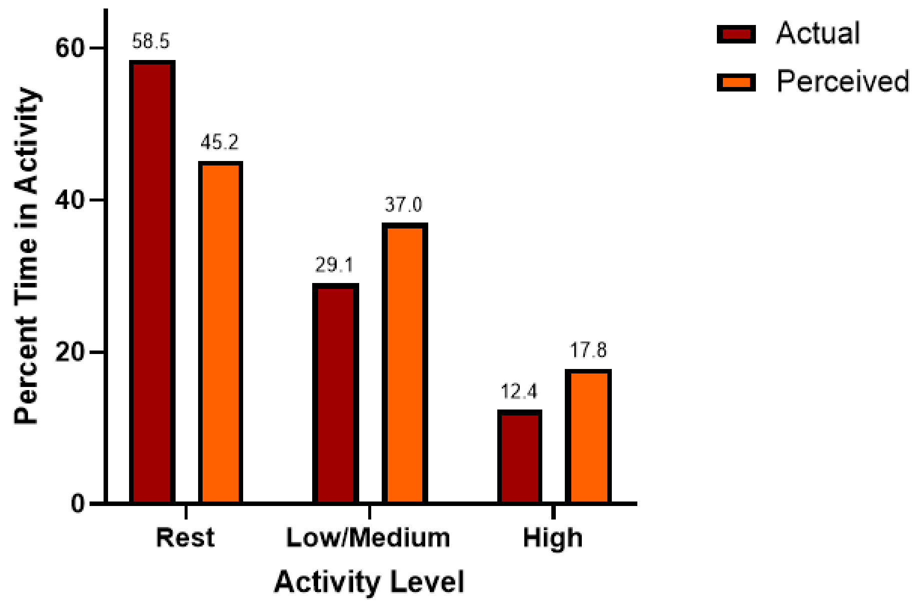
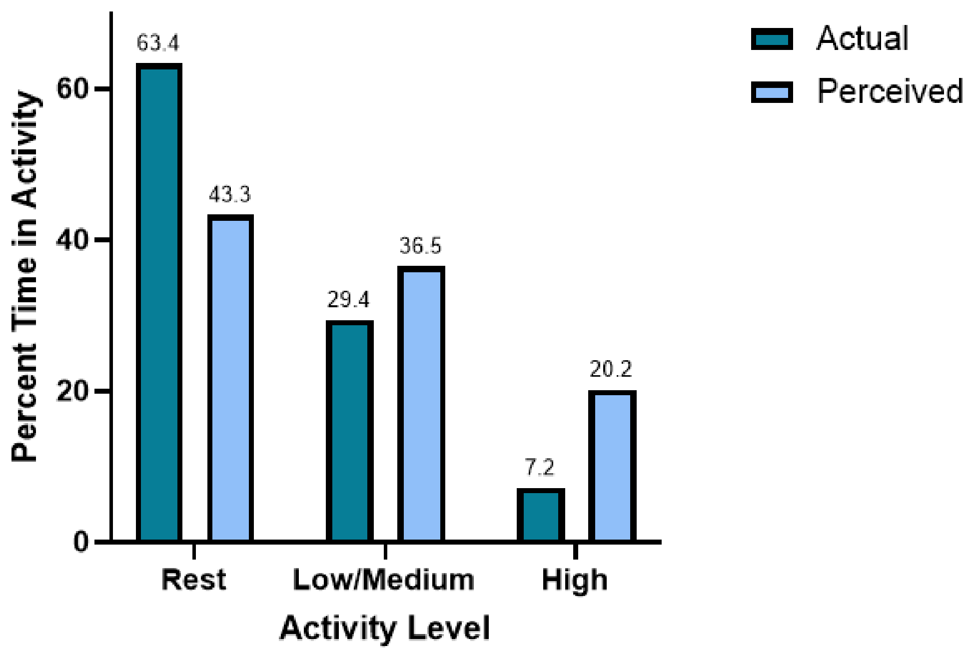


Figure 16.

Percent time spent in each activity level compared to owners and caregivers' perceptions of percent time dogs spent in each activity level in the home



4.0 Discussion

In the current study, we found that once in a home, dogs engaged in significantly more rest and less high, medium, and low types of activity. Specifically, after adoption, dogs spent a smaller proportion of their time in higher levels of activity and a greater proportion at rest. Additionally, dogs experienced a significant reduction in their pulse and respiration rates, as well as a significant increase in heart rate variability in the home as compared to the shelter. Considering that these physiological indicators of welfare improved in the home environment, while dogs also spent less time in high activity and more time at rest, it is likely that time spent in high activity as well as at rest may be worthwhile indicators of a dog's welfare. Behavioral perceptions of dogs in the shelter might not predict their behavior in the home, with caregivers reporting elements of their dog's fear, human aggression, and dog aggression higher in the home than care staff reported in the shelter, and elements of their excitability towards people as lower in the home. This study offers significant insights into how a dog's activity and behavior relate to their welfare, and how these measures change in the shelter and upon placement in a home. This is, to our knowledge, the first study using a within-subjects design to track dogs' behavior, activity, and physiological welfare from the shelter to a home over several days, demonstrating that a dog's rest and high activity levels along with their pulse, respiration, and heart rate variability are highly sensitive to environmental change.

4.1 Changes in Physiological Welfare Between the Shelter and the Home

4.1.1 Heart Rate & Heart Rate Variability

The results from the current study revealed that dogs' average pulse was lower and HRV was higher in home than the shelter. Additionally, the rate of change with both pulse and heart rate variability was greater for dogs following placement; dogs' pulse rates decreased and heart rate variability increased more quickly in the home. Nevertheless, these measures improved in the shelter too, but at a slower rate across time.

Dogs' pulse rate can significantly increase during stressful situations, such as during veterinary exams or exposure to sudden, novel stimuli, to levels as high as 170 bpm (Beerda et al., 1998; Edwards et al., 2022). Higher resting pulse rate in shelter-living dogs is associated with higher cortisol levels (Gunter et al., 2019). Similarly, dogs' heart rate variability has been shown to significantly decrease in response to stressful stimuli, along with increases in fear and stress-related behaviors when dogs are in novel social situations (Gácsi et al., 2013). Conversely, as little as 15 minutes spent being pet by a person was found to significantly increase HRV in shelter-living dogs (McGowan et al., 2018). Previously, Bergamasco et al. (2010) also found that reducing social isolation and increasing positive socialization experiences for shelter dogs can help improve their social behavior and welfare. In their study, pulse significantly decreased and HRV and social behavior increased after spending time with people outside of the shelter.

Therefore, when dogs entered a home in our study, likely with fewer stressors than the shelter environment and greater social interaction, we expected positive changes in these physiological welfare measures based on prior literature (Gunter et al., 2019; van der Laan et al., 2023a). Our current study met these expectations; dogs' average pulse rate was lower and HRV higher in home than the shelter.

To our knowledge, only one previous canine study has measured the rate of change of either pulse or heart rate variability when dogs experience different spatial restrictions in a home. This study did not detect the changes we observed, although the observation period was shorter and the manipulations may have been more subtle than in our study. In their investigation, Busato et al. (2025) found that heart rate variability did not differ between home-housed dogs living in restricted spaces in their homes compared to those living in unrestricted spaces over a 24-hour period. In a more similarly designed study with cats, Abbott (2005) found that cats' heart rate was decreased and heart rate variability increased when cats were housed in a veterinary hospital as compared to a home. No study has explored the impacts to physiological welfare during environmental transition in a within-subjects design with dogs; however, previous research by Van der Laan and colleagues (2021; 2023a) revealed that dogs' nocturnal activity decreases much faster in the home than in the shelter (two nights in the home versus about 12 nights in the shelter).

4.1.2 Respiration Rate

Respiration rates were significantly higher in the shelter environment than the home. However, the rate of change in respiration did not differ between the shelter and home. Typically, as the autonomic nervous system is activated in response to stress, changes in heart rate and respiration occur simultaneously (de Carvahlo et al., 2020). As such, we might expect that respiration rate would decrease at a faster rate in the home than the shelter, as seen with pulse rate. However, there is a considerably smaller range of respiration rates that are within normal limits (14-20 breaths per minute, range: 6 bpm) for dogs compared to the normal range for heart rate (50-83 beats per minute, range: 33 bpm; PetPace, 2025b). This difference in range of healthy heart rate and respiration rate for dogs, with much greater range for change in heart rate measurements between environments, may explain why the rate of change with heart rate would be easier to detect than the rate of change of respiration between environments.

The current study, coupled with prior literature, reveals that pulse rate, respiration rate, and heart rate variability can be collected through a wearable device and utilized as real-time indicators of a dog's welfare state (Amaya et al., 2020; Beerda et al., 1998; Bidoli et al., 2022; Katayama et al., 2016; Kuhne et al., 2014; Smith & Cohen, 2025). Each of these indicators showed marked and rapid positive changes (i.e., decreased pulse and respiration, increased HRV) upon transitioning into the home, demonstrating their sensitivity to describe dogs' experiences and their continued use as a means to understanding canine welfare.

4.2 Changes in Activity Between the Shelter and the Home

As dogs acclimated to the shelter and home environments, they engaged in less low, medium, and high activity daily with these changes in activity occurring at a faster rate in the home than in the shelter. These findings align with Van der Laan et al. (2023a), which found a decrease in both dogs' nocturnal activity as well as urinary cortisol levels across their days in the shelter. However, after adoption, dogs in their study engaged in less nocturnal activity and experienced significantly lower cortisol each day compared to their time in the shelter, with the steepest drop in nocturnal activity occurring between the first and second nights in the home. Both the study by Van der Laan and colleagues and our current investigation suggest that a dog's time in higher activity levels decreases as they adapt to new environments.

Along with spending less time in high activity in a home, dogs also showed a significant increase in rest. This extends the findings of Gunter et al. (2019, 2025), which found that uninterrupted rest and the overall proportion of rest increase when dogs are placed in a foster home for a few nights or a week, respectively. Conversely, rest does not increase during a dog's time in a shelter. The sustained stressors of the shelter likely prevent improved rest and are consistent with a compromised welfare state (Gunter et al., 2019; Van der Laan et al., 2023a). Increased time spent resting has also been found to be associated with better welfare, including a more positive judgment bias, fewer repetitious behaviors, and increased perceptions of “relaxed” behaviors in the shelter (Owczarczak-Garstecka & Burman, 2016).

The significant reduction in the rate of high activity across days in both the shelter and home is particularly noteworthy. While Hoffman et al. (2019) previously found that shelter-living dogs spent more time in high activity than home-housed dogs, their 24-hour comparison was not within-subjects. Similarly, Van der Laan and colleagues (2023a) found that dogs were significantly more active at night in the shelter compared to the home, with nighttime activity decreasing over four nights in the home. Despite this prior work, no study has explored changes in high activity across multiple full days (daytime and nighttime) using a within-subjects design and highlighted its utility as a potential indicator of welfare for shelter-living dogs.

Assessing the welfare of animals living in shelters can be a complex endeavor (Lamon et al, 2021). Typically, welfare is evaluated through examinations of dogs’ physical health along with observing behaviors associated with compromised welfare, such as panting, circling, or barking (Protopopova, 2016). However, given the number of dogs present in shelters and the varying knowledge of staff, it might be difficult to accurately and routinely assess dogs’ behavior with the potential for more subtle cues of compromised welfare to be missed in daily interactions (Diederich & Giffroy, 2006; Gilchrist, 2024). Engagement in high activity in-kennel includes highly observable and distinct behaviors, such as jumping, circling, or pacing, that may be easier for shelter staff to note, even without specialized training in canine behavior (PetPace, 2025a; Khoshnegah et al., 2011).

As such, the novel findings regarding the association between elevated time spent in high activity and reduced physiological welfare from this study is particularly valuable, and future studies should explore the utility of high activity measurement, either through observations or accelerometers, as a functional tool for welfare assessment in animal shelters (Stephen & Ledger, 2005). Additionally, we found the rate of high activity engagement significantly declines across days in *both* environments, likely due to the dog acclimating and a decline in stress (Van der Laan et al., 2021), further highlighting the importance of high activity in shelter welfare measurement. Lastly, beyond the importance of high activity as a reflection of dogs' immediate welfare, both increased activity and movement in the kennel have been associated with longer lengths of stay for dogs (Ampaiwan, 2022; Protopopova et al., 2014), further emphasizing the impact of activity on their experiences in the shelter.

4.3 Perceptions of Behavior and Activity

Furthermore, our C-BARQ findings indicate differences in the ratings about dog- and human-aggressive behavior that we collected in the shelter (as measured by care staff) and in the home (as measured by adopters and foster caregivers). Adopters and caregivers rated their dog's aggression higher in two scenarios: when an unfamiliar dog barked, growled, or lunged at them on-leash, and when an unfamiliar person tried to touch or pet them. Shelter staff reported higher aggression when dogs were approached by other dogs in their kennel than adopters and caregivers reported when approached by another (familiar) dog in the home. However, dogs' aggression was consistently rated as mild, at most, in both environments, which is consistent with Mornement et al. (2014), but less than the average level of aggression described by adopters in Duffy et al. (2014) and Bohland et al. (2023). Additionally, the selection of highly sociable dogs for the Shelter Dog Training course might explain the lower severity of aggression we observed in our study.

One explanation for the difference in ratings of these aggression-related behaviors is that owners and care staff perceive and rate these behaviors differently. About 42% of caregivers who responded to the survey were first-time caregivers, without a previous history of owning or fostering a dog. Owners may possess less knowledge of dog behavior than care staff working in a shelter, particularly if they are first-time owners, which may lead them to misinterpret dog's aggressive behavior or fail to recognize aggression-related problems (Powell et al., 2021). Nevertheless, our results echo previous findings about the behavior of dogs in shelters versus homes. Christensen et al. (2007) found that 40.9% of dogs reported as non-aggressive in the shelter later showed dog- or human-directed aggressive behaviors in the home. In Bohland et al. (2023), post-adoption C-BARQ ratings about dogs' aggression toward unfamiliar people tended to increase over time, rising from 61.5% near adoption to 76.9% at 180 days. Adopters also reported a high prevalence of dog-directed aggression (75%) that increased post-adoption. In total, this suggests that an adopted dog's aggression toward unfamiliar people and dogs, although mild, may increase over time, and that measurements taken in the stressful environment of the shelter may not reliably predict in-home behavior.

It is also possible that differences in handling influenced the experiences of care staff and adopters in our study. In previous research, over half of UK home-housed dogs have been found to interact with one to five dogs daily and about two-thirds encounter unfamiliar humans on walks. Conversely, shelter protocols often involve walking dogs on-leash at a distance from other dogs and people, limiting their exposure to close passes or petting by strangers. Consequently, dogs in homes are more likely to interact with unfamiliar dogs and people on a leash, increasing the opportunity to display aggressive behavior (Westgarth et al., 2015). Environmental differences may explain why shelter staff rated the dogs as more aggressive when walking past the kennel than adopters in the home. In the shelter, dogs must walk past other dogs in close proximity multiple times a day to enter and exit the kennels, therefore providing more opportunities for shelter care staff to potentially observe this behavior. In the home, such an analogous scenario may not be presented as often with other dogs or a resident dog, leading to fewer opportunities for caregivers to observe this in the home.

Moreover, adopters and caregivers might observe more aggressive behavior on-leash if they have missed the subtle signs of discomfort their dogs have expressed towards people or other dogs (Animal Humane Society, 2025). While living in the shelter environment at the university, dogs may have been more expectant of positive social interactions due to the course's reinforcement-based curriculum and many daily interactions with students, care staff, and potential adopters. Care staff in the shelter were also knowledgeable in basic dog behavior and training, which likely aided in their recognition of more subtle signs of stress, offering opportunities to improve their dogs' comfort in these scenarios reducing dogs' need to escalate to aggression (Philpotts et al., 2019).

In exploring differences in dogs' fear behavior as rated by individuals in the shelter and home, we found that adopters and caregivers reported greater fearful behavior in the home when an unfamiliar dog barked, growled, or lunged at the dog on-leash as well as when dogs were exposed to unfamiliar situations or sudden or loud noises in the home. It is possible that dogs display less fearful behavior in the shelter, yet the presence of fearful behavior of dogs in this stressful environment has been well-documented (Collins et al., 2022; Demirbas et al., 2014). Nevertheless, situational differences are crucial to consider.

Differences in environmental stressors may also contribute to differences in fearful behavior reported in the shelter and in the home. In the shelter, sudden loud noises may be less salient relative to the environment's overall excessive noise and might be less likely to elicit observable fear. In a quieter home, sudden, high-frequency noises (such as smoke alarms or sirens) might be more distinct and elicit observable fearful behaviors. Nearly 40-50% of dogs in homes have a degree of noise sensitivity or response (Blackwell et al., 2013; Grigg et al., 2021). Furthermore, dogs coming from a shelter into a home are often exposed to an abundance of novel stimuli during their transition. A study in New Zealand found that 25% of adopters report some level of fearful behavior with their adopted dog toward unfamiliar situations and stimuli (Gates et al., 2018). Meanwhile, Wells and Hepper (2000) found that fearfulness was the most common behavioral concern reported shortly after adopting a dog.

Arousal, or "displaying strong reactions to potentially exciting events" (Hsu & Serpell, 2003), was the only type of behavior that did not vary in our shelter and home ratings. Given the known stressfulness of the shelter, we expected arousal-related behaviors to decline once a dog was adopted or fostered as previous literature has shown that dogs' cortisol levels decline once in the home (Gunter et al., 2019; Van der Laan et al., 2023). Nevertheless, the opposite was found, demonstrating that a dog's arousal behavior in the shelter is most similar to their in-home behavior. While this contrasts with our accelerometer-based finding that high activity is lower in the home, it is possible that the C-BARQ measurement of arousal might be unrelated to the dogs' high activity and instead describes dogs' responses to particularly salient and transient stimuli, and such responses might remain consistent across environments.

Dogs were reported to have higher human-related excitability, or strong reactions to situations involving human interaction or human-centric events (Hsu & Serpell, 2003), when visitors arrived at their kennel in the shelter compared to when visitors arrived at the home. One of the greatest stressors for shelter dogs is social isolation (Beerda et al., 1999a,b; Hennessy et al., 1997). In the shelter, with limited and inconsistent human interaction, social isolation may increase dogs' excitability when approached by a visitor. Past research has shown that shelter dogs have higher disinhibited attachment than owned dogs and are unbiased in seeking proximity from a known caregiver versus an unfamiliar person (Thielke & Udell, 2020). As such, shelter-living dogs might be more likely to display excitable behaviors towards anyone arriving at their kennel in hopes of interacting; while dogs in a home might be less socially isolated and not seeking out interactions to the same degree with people. Future studies exploring dogs' attachment styles immediately following adoption would likely improve our understanding of changes in their excitability when interacting with strangers.

4.4 Implications

In many ways, the shelter environment at the Virginia-Maryland College of Veterinary Medicine (VMCVM) simulated a traditional shelter; dogs were singly-housed in kennels and known shelter stressors including noise, confinement, and isolation were present. However, while being housed at VMCVM, dogs were also receiving six sessions of walks, training, and play with student handlers and care staff each day. As such, dogs in this study were likely receiving greater opportunities for social interaction and time spent out of the kennel, which are known opportunities for stress reduction for shelter-living dogs (Bergamasco et al., 2010; McGowan et al., 2018), than would be expected at a typical shelter. Even with these opportunities for enhanced welfare, dogs' physiological indicators of welfare were still significantly poorer than in the home. If the current study were replicated in a typical shelter environment, we would expect that the differences in dogs' physiological welfare may be even more pronounced between environments.

The current study revealed that the rate of change in pulse and HRV is faster in the home than in the shelter, which introduces a novel finding: the rate of physiological acclimation may provide its own very valuable insights into the impact of an environment on a dogs' welfare. These results indicate that the home environment provides a rate of welfare improvement that exceeds any reduction in stress through time spent in the shelter. When coupled with previous research on the improvements dogs experience in rest, nocturnal activity, and cortisol once leaving the shelter (Gunter et al., 2019; van der Laan et al., 2023a), we can continue to uncover evidence that allowing dogs short reprieves in foster care may help improve their physiological welfare in ways that would be relatively unlikely in the shelter.

Both care staff in the shelter and caregivers in the home tended to misestimate the amount of time that dogs spent in various types of activity, with both groups underestimating the amount of time dogs rested and overestimating how much time they were active. Such misconceptions about dogs' activity may have a negative effect on dogs' sheltering experience and length of stay in the shelter. Archer et al. (2025) found that adoption profiles that included the word, energetic, reduced dogs' perceived adoptability. Meanwhile, a study that explored the online adoption profiles in Australia found that not describing dogs as energetic was associated with the shortest stays for dogs in the shelter (Nakamura et al., 2019). These findings, taken together with our results, would suggest that shelter-living dogs' activity is likely misunderstood as compared to accelerometer-derived data. Furthermore, such misperceptions about dogs' activity could have detrimental effects on dogs' welfare in the shelter and would benefit from further exploration.

Behavioral findings from this study revealed that aggression and fear-based behaviors in particular were often rated higher in the home than in the shelter, suggesting that behavioral observations in the shelter may not reliably predict the full range of a dog's behavior once in a home, as other researchers have also asserted (Gilchrist, 2024). Nevertheless, our finding that certain some fear- and aggression-related behaviors increase for dogs post-adoption, along with the prevalence of these behaviors post-adoption that has been found in previous literature (Gates et al. 2018; Wells & Hepper, 2000), highlights a critical need for accessible post-adoption support programs for dog owners (Powell et al., 2022; Gates et al, 2018). These programs should focus on behavioral education to help them identify more subtle signs of stress and discomfort (which may be missed by less experienced owners) and provide strategies that support positive interactions with people and other dogs (Buckland, 2025; Animal Humane Society, 2025).

4.5 Limitations

A total of three dogs' data was removed from our statistical analysis due to their inability to wear a health monitoring collar in the home, reducing the final sample size to 19 dogs. Given that this is a mixed-effects study with random effects to model the natural variability in participating dogs, having a smaller sample size limited our statistical power, although the numerous readings from the health-monitoring collars mitigated those issues to some degree. Replicating this study with more dogs, including those from more typical shelters, would help to better understand the effects we observed and their generalizability to a wider population of shelter-living dogs.

Proprietary algorithms that are created by PetPace are designed to exclude species-specific canine vocalizations in acoustic sensor readings, including panting, barking, and whining. These algorithms are designed to ensure that pulse, respiration, and heart rate variability readings reflect changes in dogs' low-signal internal acoustic signals from contractions within the heart, lungs, and blood vessels. However, with a large variation in possible vocalizations as well as external acoustics in both shelter and home environments (Blackwell et al., 2013; Grigg et al., 2021; Sales et al., 1997), there is potential for errors in the algorithm's filtering and data handling.

Similarly, proprietary algorithms within the collars are designed to categorize activity into four levels: rest, low, medium, and high activity. This method of categorization contributes to lesser transparency on the classification of dogs' actual activity. Additionally, by using categorical variables for activity rather than raw acceleration counts (i.e., m/s^2), this approach removes the ability to detect smaller changes in dogs' activity. In the future, utilizing raw accelerometer data might allow for more nuanced detection of changes in activity over time within each category.

Heart rate variability (HRV) was measured using the vasovagal tonus index (VVTI) – an indirect method that assesses parasympathetic nervous activity, which is primarily controlled by the vagus nerve. VVTI is derived by calculating variation in consecutive R-R intervals in heart rate over a one-minute period. With calculations using only consecutive beats at a time over one-minute, this type of HRV calculation is often more preferred for measuring short-term changes in the autonomic stress response system, rather than longer-term changes, which were the focus of our present study. If outputs from health monitoring collars utilized SDNN, or the standard deviation of time intervals between normal heartbeats, instead of VVTI, this might be a better way to measure changes in heart rate variability over time (Fernandes & Sears, 2021).

Dogs were placed into adoptive and foster homes that varied in the numbers and ages of resident people, home sizes and types, and access to outdoor spaces. Homes or apartments were only in rural or suburban areas; by chance, no dogs were placed in urban settings. Additionally, nearly all dogs in our study were adopted into homes with zero to one other resident dog and with no additional resident pets. Only one dog was adopted into a home with three additional resident dogs and multiple resident cats. As such, these similarities in the locations and number of residing pets in foster or adoptive homes indicate that the home environments utilized in this study are not representative of all home environments in the United States, especially those in urban areas or homes with multiple resident dogs or pets. Continuation of this study with a wider range of foster and adoptive homes in urban areas, various geographic locations, and with a wider range of resident pets in home would help better characterize and understand dogs' experiences post-placement.

Differences in dogs' routines between the shelter and home environments may have also influenced their activity, pulse, respiration, and heart rate variability measures, irrespective of the differences in environmental living conditions themselves. In the shelter, dogs received a more structured routine of multiple daily interactions, walks, training sessions, and enrichment from several student handlers and care staff, each of which could have altered their activity levels. Meanwhile, in the home environment, daily activities may have occurred less often with fewer people. Moreover, variables such as number of people in the home and interactions with other pets may have also influenced dogs' activity levels and were not recorded as part of this study. Similarly, in home environments, times spent walking, training, interacting, playing, or feeding likely varied extensively across homes, which may also have influenced dogs' pulse, respiration, and HRV. If this study were to be replicated, questions about caregivers' routines with their dogs (i.e., number of interactions, timing of feeding and walks, other individuals and pets in the home) could help researchers appreciate how individual differences in dogs' daily experiences may affect their welfare.

Another limitation of the current study involves the behavior and activity surveys completed by adopters and caregivers in the home and care staff in the shelter as they rely on human perception of behavior, which likely differed significantly between trained care staff and adopters and caregivers in the home. Those that care for dogs in homes have a range of understanding of dog behavior and accuracy in their reporting (Munch et al., 2019; Powell et al., 2021). Inter-observer reliability between the groups in our study may have been reduced due to differences in behavioral understanding. Additionally, adopter and caregiver's attachment to their dogs can lead to potential bias in questionnaire responses and underreporting undesirable behaviors (Powell et al., 2021). Asking adopters and caregivers, as well as staff, to submit videos of their dogs' engaging in behaviors discussed on the survey, later coded by trained research assistants, may be a way to increase inter-rater reliability and accuracy of behavioral responses.

While dogs in this study wore health monitoring collars for the longest duration that has been described thus far in the scientific literature, 20 days pre- and post-adoption was likely insufficient to fully capture and describe dogs' experiences in the shelter and home. Absent a longer window of data collection in which dogs achieve stability across our measures of activity and physiology, it remains unknown the duration of time dogs need to fully acclimate to these environments. Future studies, particularly in the home, exploring this question would add to our understanding of the adjustment period dogs experience following placement and improve our behavioral support of adopters and foster caregivers.

5.0 Conclusions

This study investigated the impacts of the environment on dogs' physiology, activity, and behavior. The results showed that dogs are more likely to rest in a home while also engaging in more high activity in the animal shelter. Meanwhile, physiological measures (i.e., pulse, respiration rate, and HRV) were negatively impacted in the shelter versus the home, demonstrating distinct differences in the body's most basic functioning between these environments. Based on these results, animal shelters should continue their efforts to improve the experience of dogs in their care through the monitoring of activity, specifically time spent at rest and in high activity, as they appear to be most clearly linked to changes in physiology associated with stress, and easily observable in the shelter environment. Nevertheless, it is probable that shelter staff, as well as adopters and caregivers, underestimate the amount of time dogs rest and overestimate their engagement in high activity based on observation; this further highlights the utility of health and activity monitoring technologies in the shelter to support staff in the caring of many dogs within this environment.

Dogs' behavior, particularly fear-based and aggression-related behaviors, were reported to be more prevalent in the home than the shelter, although mild in both environments, indicating that behavioral observations in the shelter may not be consistent with experiences in the home. Differences in reports of dogs' fear-based and aggression-related behaviors between environments may be due in part to differences in understanding of canine behavior and training between adopters and care staff, thereby reducing opportunities to recognize signs of canine stress, provide positive reinforcement, or manage disconcerting environmental stimuli to lessen discomfort for their dog. Although the literature surrounding changes in dogs' behavior following adoption is mixed, our findings support the continued need for post-placement support and training for dog owners to help reduce behavioral concerns in the home.

Furthermore, high activity in the animal shelter does not necessarily predict a need for placement in an active home as dogs' high activity decreases following placement. Instead, dogs showing little rest or greater high activity while living in the shelter are likely those most in need of an intervention. The observed increase in rest and decrease in high activity, along with lower pulse and respiration rates and higher heart rate variability, in the home suggest that leaving the shelter, be it through foster care or an adoptive placement, could significantly enhance the welfare of dogs. Moreover, our finding that dogs' activity did not differ between adoptive and caregiver homes is promising support that foster placement, prior to adoption, can assist shelters in gathering useful information about dogs in a home environment while improving their welfare.

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