The curious incident of the dog in the nighttime:

An examination of pet-human co-sleeping and dyadic sleep measurement

Hillary Rowe

A Thesis

In

The Department

Of

Psychology

In Partial Fulfillment of the Requirements

For the Degree of Master of Arts (Psychology) at

Concordia University

Montreal, Quebec, Canada

August 2019

CONCORDIA UNIVERSITY
School of Graduate Studies

This is to certify that the thesis prepared

By: Hillary Rowe

Entitled: The curious incident of the dog in the nighttime: An examination of pet-human co-sleeping and dyadic sleep measurement

and submitted in partial fulfillment of the requirements for the degree of

Master of Arts (Psychology)

complies with the regulations of the University and meets accepted standards with respect to originality and quality.

Signed by the final examining committee:

______________________________	Chair	Dr. Andreas Arvanitogiannis
______________________________	Examiner	Dr. Kristen Dunfield
______________________________	Examiner	Dr. Aaron Johnson
______________________________	Examiner	Dr. Rex Kline
______________________________	Thesis Supervisor(s)	Dr. Jennifer McGrath

Approved by ____
Chair of Department or Graduate Program Director

____
Dean of Faculty

Date ____

ABSTRACT

The curious incident of the dog in the nighttime:

An examination of pet-human co-sleeping and dyadic sleep measurement

Hillary Rowe

Many pet owners report sharing a bed with their pets, but little is known about the effects of pet-human co-sleeping, particularly in children. The overarching goal of this thesis was to increase knowledge of the measurement and effects of co-sleeping with pets. The objective of the first study was to compare sleep dimensions between children who co-slept with pets and those who did not. Children and adolescents completed questionnaires about sleep habits, kept a daily sleep log, and wore actigraphs for two weeks. Pet co-sleeping groups had similar sleep profiles and there were no differences between groups on subjective or objective sleep. The objective of the second proof-of-concept study was to consider methodological challenges in dyadic sleep research by testing novel assessment methods. A small convenience sample of dog-human dyads was recruited to wear accelerometers and proximity sensors. Participants completed a series of pet attachment questionnaires. Proximity sensors produced poor quality data and did not adequately measure distance between pets and humans. Dyadic accelerometry appears feasible and yields comparable data for humans and dogs.

ACKNOWLEDGEMENTS

First and foremost, I would like to thank Dr. Jennifer McGrath for her support, patience, and willingness to take a risk on this project. I would like to thank David Munro for providing invaluable technical assistance and expertise. I would also like to thank my committee members, Drs. Kristen Dunfield, Aaron Johnson, and Rex Kline for their enthusiasm and feedback. Finally, I would like to thank the members of the Pediatric Public Health Psychology Laboratory for their help with my project.

CONTRIBUTION OF AUTHORS

For Study 1, Hillary Rowe developed the research question, conducted the literature review, collected, cleaned, and synthesized data, undertook the statistical analyses, interpreted the results, and wrote and revised manuscripts. As Hillary's research supervisor, Dr. Jennifer J. McGrath co-developed the research questions, obtained grant funding support from the Canadian Institutes of Health Research, collected research data, coordinated research data management, supervised the statistical analyses and results interpretation, and revised manuscripts.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

GENERAL INTRODUCTION

Pet ownership is increasingly prevalent in developed nations. Approximately 56% of Canadian households include at least one dog or cat, and pet ownership rates are estimated to exceed 70% in families with children (Downes et al., 2009; Perrin, 2009; Westgarth et al., 2010). Pets are highly valued by their owners, who often consider them to be family members. Consequently, it is not surprising that many pet owners report sharing their beds with their pets (Krahn, Tovar, & Miller, 2015).

Although prevalent, pet-human co-sleeping has been the subject of little research. To date, studies in this area have yielded inconclusive findings, and the impact of pets on human sleep remains unclear. Past studies generally had small sample sizes, inadequate controls, and a lack of comprehensive sleep measurement. Moreover, no research exists to clarify the relation between pet-human co-sleeping among children. Given the rate of family pet ownership in childhood, this represents a significant gap in the literature.

The purpose of this thesis was twofold. Study 1 aimed to examine sleep among children who co-sleep with pets compared those who do not, using multiple assessment methods to precisely measure sleep. The goals of Study 2 were to test proof-of-concept methodology for future pet-human co-sleeping research by: (i) testing proximity measurement, (ii) evaluating simultaneous use of accelerometry in dyads, and (iii) refining psychometric assessment of one's attachment to pets. The following background sections include: the social, psychological, and health-related effects of pet ownership; a concise overview of sleep; and, a review of previous co-sleeping research will be presented,

Pet Ownership: Social, Psychological, & Health-related Effects

Social relationships are not limited to other people; many people consider their pets to be an important source of social interaction and social support. Pet companionship appears to have similar positive effects to social relationships with humans, and both children and adults have even reported valuing their relationships with their pets *more* than some human relationships due to the social support and unconditional positive regard that they provide (McConnell et al., 2011; McNicholas & Collis, 2001). Furthermore, pet ownership has been linked to enhanced psychological wellbeing, including reduced risk for depression, lower perceived stress, and more positive mood (McConnell et al., 2011; Siegel et al., 1999).

Numerous physical health benefits have also been associated with pet ownership. A growing body of research has focused on pets and cardiovascular health; pet ownership is associated with better cardiovascular functioning, as well as improved recovery and survival following myocardial infarction and other cardiac conditions (Friedmann & Thomas, 1995). In fact, the American Heart Association concluded that pet ownership may have a *causal* role in reducing risk for cardiovascular disease (Levine et al., 2013). Experimental studies demonstrate that the presence of pets buffers cardiovascular and cortisol reactivity in response to stressors. Allen, Blascovich, and Mendes (2002) found that married adults had lower baseline heart rate and blood pressure when their pets were present, and that they experienced smaller increases from baseline levels in response to laboratory stressors than those who completed the tasks in the presence of a spouse or friend. Similarly, Allen et al. (2001) conducted a randomized study of pet ownership and cardiovascular reactivity, in which individuals with high-stress occupations who wanted to adopt pets were assigned to adopt or not. After six months, pet owners showed smaller increases in blood pressure, heart rate, and plasma renin activity in response to a laboratory stressor (completed in the presence of their pets) than non-pet owners.

Pets have a significant positive influence on their owners' health. Specifically, there is convincing evidence that pets decrease cardiovascular reactivity, reduce stress, and promote psychological functioning in both children and adults. However, given that social relationships are known to broadly affect health and health behaviours, it is likely that pet ownership plays a role in other aspects of health. In particular, pet ownership may influence sleep. Sleep represents both an important social context and a critical health behaviour; many people report sharing a bed with their pets, and this likely has direct and indirect effects on their health.

Concise Overview of Sleep

Sleep is a multidimensional physiological state that varies considerably between individuals. While the physiology of sleep is not the focus of the current study, a concise overview follows as it important for a foundational understanding of key sleep dimensions and dyadic sleep measurement. Briefly, sleep includes two primary states that occur in a cyclical, alternating pattern: rapid eye movement (REM) and non-rapid eye movement (non-REM). REM sleep is associated with elevated blood pressure, heart rate, and respiration (i.e., sympathetic dominance), and loss of muscle tone to inhibit movement. Non-REM sleep involves increased parasympathetic dominance and restorative processes (van Eekelen, Varkevisser, & Kerkhof, 2003). Non-REM sleep is subdivided into three stages: stages 1 and 2 are considered light sleep, while stage 3 is described as slow-wave or deep sleep and is thought to be more restorative than stages 1 and 2.

Sleep is typically quantified as total duration (i.e., number of hours spent sleeping); however, other sleep dimensions are equally (or more) important for health and functioning (Jarrin, McGrath, & Drake, 2013). Other sleep dimensions include fragmentation, disturbances, latency, efficiency, timing, circadian preference, and quality. *Sleep fragmentation* refers to frequent interruptions in sleep. *Sleep fragmentation* is quantified as wake after sleep onset (i.e., minutes spent awake after falling asleep) and number of awakenings. Greater fragmentation typically results in sleep that is less refreshing or restorative. *Sleep disturbances* include sleep disorders (i.e., insomnia, sleep apnea, parasomnias). Sleep latency refers to the time spent trying to fall asleep (i.e., onset). *Sleep efficiency* is the amount of time in bed spent sleeping. Sleep is also influenced by *timing* (i.e., bedtime, waketime) and its correspondence with one's *circadian rhythm* or preference (i.e., endogenous clock). This is especially relevant for adolescents, many of whom experience delayed sleep phase in which their endogenous circadian rhythm promotes falling asleep and awakening later than children and adults (Crowley, Acebo, & Carskadon, 2007). This "developmentally normal" shift in circadian rhythms during adolescence is further exacerbated by early school start times, which can lead to reduced sleep duration, greater daytime sleepiness, and social jetlag (i.e., going to bed and waking up later on weekends than during the week; Wittmann, Dinich, Merrow, & Roenneberg, 2006). Finally, *sleep quality* reflects perception of and satisfaction with one's sleep. Subjective sleep quality has been associated with depth (i.e., time spent in slow-wave sleep) and continuity (i.e., amount of fragmentation) of sleep (Keklund & Akerstedt, 1997).

Co-Sleeping and Sleep Quality

Sleep research has traditionally focused on sleep as a solitary phenomenon, with the majority of studies neglecting to consider co-sleeping and other social and environmental contextual variables. While this approach may be diagnostically sound for identifying sleep disturbances or disorders, it has poor ecological validity when examining sleep among the general population. Individuals commonly share a bed with other people; over 60% of adults sleep with a partner (Troxel, Robles, Hall, & Buysse, 2007), and between 25 - 45% of parents regularly share a bed with their infant or child (Blair & Ball, 2004; Li et al., 2008; Oskar et al., 2005). Furthermore, among adult pet owners, between 31 - 56% report sharing a bed with their pets (Hoffman, Stutz, & Vasilopoulos, 2018; Krahn et al., 2015).

Most co-sleeping research to date has been conducted with adult couples. Briefly, adults commonly exhibit better objective sleep quality when sleeping *alone*, including decreased sleep latency (time to fall asleep), increased sleep efficiency (time in bed spent sleeping), and less movement (nighttime arousals); however, they report greater subjective sleep satisfaction when sleeping with their *partners*, highlighting the critical role of social context (Troxel, Robles, Hall, & Buysse, 2007). Similarly, sleeping with a partner has been linked to enhanced relationship quality and feelings of security, and marital happiness has been associated with better sleep (Troxel, Buysse, Hall, & Matthews, 2009). Previous research also investigated the influence of sleep concordance (i.e., similarity of partners' sleep patterns and timing) and partners' movements on sleep quality. Co-sleeping was associated with increased nocturnal movement and sleep disturbances, but even among individuals frequently woken by partners' movements, they still preferred sharing a bed and reported greater satisfaction than when sleeping alone (Pankhurst et al., 1994).

Co-sleeping is also common among parents with their children, particularly in infancy and early childhood. Few studies have investigated the effects of parent-child co-sleeping in children past infancy, especially in Western countries. Sharing a bed in childhood has been linked to children's increased sleep disturbances and poorer subjective sleep quality. However, the relation is complex as co-sleeping is often associated with lower socioeconomic status and household crowding, as well as children's sleep problems, nighttime fears, and anxiety (Cortesi et al., 2008; Li et al., 2008; Liu, Liu, & Wang, 2003; Lozoff et al., 1984). These confounding factors may negatively impact sleep quality beyond the effects of parent-child bed sharing. In cultures where sharing a family bed is socially acceptable and quite common, co-sleeping has shown no negative effects, and may even improve sleep, promote family bonding, and reduce psychological distress for certain children (Worthman & Brown, 2007; Yang & Hahn, 2002). Family co-sleeping may be problematic for children primarily when it is perceived as unacceptable, in chaotic household conditions, or among children who have sleep issues.

Studies on pet-human co-sleeping are limited, but largely mirror findings from the adult couples literature. Pet owners tend to perceive co-sleeping with pets as beneficial and calming, yet show worse sleep when measured using actigraphy (Krahn et al., 2015; Patel et al., 2017;

Smith, Browne, Mach, & Kontou, 2018). The reasons for this discrepancy are unclear, and co-sleeping studies in both adult-adult dyads and pet-human dyads have failed to establish causality between one bed partner's movements and the other's sleep quality. It is plausible that a methodological issue may be indicated as the majority of these studies have used actigraphy to measure sleep.

Sleep Assessment & Dyadic Measurement

There are many methods of assessing sleep. The most common approaches in research include self-report questionnaires, sleep diaries, actigraphy, and polysomnography (PSG). Questionnaires are an efficient and cost-effective method of gaining insight into an individual's perceptions of their sleep, particularly with respect to sleep quality, sleep patterns, sleep disturbances, sleep-related behaviours or habits, and sleep context. They provide valuable information about a person's sleep-related experiences and can be useful in identifying sleep problems. Measures such as the Children's Sleep Habits Questionnaire (CSHQ; Owens, Spirito, & McGuinn, 2000) and Pittsburgh Sleep Quality Index (PSQI; Buysse, Reynolds, Monk, Berman, & Kupfer, 1989) have demonstrated good clinical utility and convergent validity (Carpenter & Andrykowski, 1998; Grandner, Kripke, Yoon, & Youngstedt, 2006; Markovich, Gendron, & Corkum, 2015). Sleep diaries are another subjective measure used to capture nightly variations in sleep. They are useful for assessing patterns and changes in sleep timing, awakenings, and disruptions, and also for supplementing objective sleep measures (e.g., actigraphy, polysomnography). Sleep diaries such as the Consensus Sleep Diary (CSD; Carney et al., 2012) have shown good utility and validity in healthy and clinical samples (Carney et al., 2012; Maich, Lachowski, & Carney, 2018).

Actigraphy (i.e., accelerometry) involves the continuous recording of bodily movement, typically on the wrist or waist. The wearer's acceleration is measured using the piezoelectric effect, which uses piezoelectric material as a transducer to convert movement into a current (John & Freedson, 2012; Lamprecht, 2014). Signal processing yields the quantification of periods of sleep and wakefulness as well as sleep dimensions (e.g., latency, awakenings). Actigraphy is generally considered to be an "objective" form of sleep assessment because it does not rely on participants' self-reports of their sleep. However, actigraphy data are scored manually, and outcomes can vary depending on scoring algorithm, signal processing, and subjective decision-making. Actigraphy has moderate to strong reliability and validity compared to polysomnography (PSG; Sadeh, 2011); however, its accuracy during co-sleeping has not been evaluated, despite criticisms that the presence of a bed partner might introduce error (Sadeh, Hauri, Kripke, & Lavie, 1995; Tryon, 2004). PSG is the gold-standard in sleep measurement, and includes recording of multiple physiological signals (EEG, eye movement, muscle activity, heart rhythm) by placing electrodes on the head and body. PSG permits examination of precise sleep architecture parameters (i.e., staging) and is more robust against measurement error than actigraphy.

Sleep measurement has long been an issue in co-sleeping research, as most methods are designed and validated for use in individuals during solitary sleep. Few, if any, studies have psychometrically evaluated sleep assessment devices or self-report measures in dyads. It is generally acknowledged that the presence of another being might alter one's sleep; yet, researchers continually fail to consider this when selecting assessment tools, creating new measures, or conducting psychometric studies. Co-sleeping has been measured in numerous ways, including daily diary studies (Hasler & Troxel, 2010), actigraphy (Gunn, Buysse, Hasler, Begley, & Troxel, 2015; Meadows, Arber, Venn, Hislop, & Stanley, 2009; Pankhurst & Home, 1994), and polysomnography (PSG; Beninati, Harris, Herold, & Shephard, 1999). However, co-sleeping research findings have been inconsistent and inconclusive, likely due in part to these salient measurement issues. For example, the majority of studies used actigraphy. Because actigraphy uses movement to estimate sleep, it is possible that external activity (i.e., partner's movment) might interfere with its accuracy. The increased movement and sleep disturbances observed while co-sleeping may be due to bed partners' activity, especially considering that co-sleepers do not report worse subjective sleep.

Thesis Objective

The primary objective of this theses was to improve our knowledge of pet-human co-sleeping and dyadic sleep measurement. This thesis consists of two complementary studies. Given the prevalence of co-sleeping with pets and its likely impact on sleep, Study 1 compared sleep dimensions among children who co-sleep with pets, using different assessment methods to measure sleep. The results of Study 1 raised new questions about the methodological limitations for co-sleeping research and how to optimally and accurately quantify dyadic sleep. Thus, Study 2 was a proof-of-concept project to inform future co-sleeping research. Human-pet dyads provide a unique model to study co-sleeping and to isolate methodological parameters that may influence dyadic sleep measurement. As such, this proof-of-concept project was thought to provide an ideal starting point for future studies that could be extended to other co-sleeping dyads (e.g., adult couples; parent-child dyads).

Study 1:

Effect of Co-Sleeping with Pets on Children's Sleep

Introduction

The quality and quantity of social relationships have been empirically shown to promote physical health and psychological wellbeing (Holt-Lunstad, Smith, & Layton, 2010; House, Landis, & Umberson, 1988; Uchino, Cacioppo, & Kiecolt-Glaser, 1996). Although people typically seek social interaction from friends and family members, social relationships are not limited to humans; many people view their pets as an integral component of their support systems. A growing body of research suggests that pets provide comparable health and social benefits to human relationships, including greater perceived social support (McConnell et al., 2011), reduced risk for depression (Siegel et al., 1999), and improved cardiovascular health (Friedmann & Thomas, 1995). Experimental studies indicate that pets buffer cardiovascular and cortisol reactivity in response to stressors (Allen, Blascovich, & Mendes, 2002; Kertes et al., 2017) and, in fact, the American Heart Association concluded that pet ownership may have a *causal* role in reducing risk for cardiovascular disease (Levine et al., 2013). It is increasingly evident that pets are beneficial for human health, with past research focused predominantly on cardiovascular functioning and stress. Pets' influence on other aspects of health, however, has largely been neglected.

Pet owners often view their pets as family members, and enjoy spending as much time with them as possible, even when they are asleep. More than 50% of adult pet owners report *sharing their beds* with their pets (Hoffman, Stutz, & Vasilopoulos, 2018; Krahn, Tovar, & Miller, 2015; Thompson & Smith, 2014), yet few studies have examined the role of sleep in pet-human relationships. There is little consensus regarding the impact of co-sleeping among bed partners. Much less is known about the effects of pet-human co-sleeping on pet owners' sleep. Pets are often thought to be detrimental to sleep due to nocturnal activity or noises they emit (Krahn et al., 2015; Smith et al., 2014). Many health professionals advise against allowing pets in the bedroom at night, and recommendations to improve sleep hygiene and sleep quality often imply pets are a source of sleep disruption (Bloom et al., 2009; Noland, Price, Dake, & Telljohan, 2009). However, there is limited evidence to support these claims, and many pet owners describe co-sleeping with their pets as comforting and relaxing (Krahn et al., 2015). Brown, Wang, and Carr (2018) found that 80% of adults with chronic pain viewed co-sleeping with their pets as beneficial to their sleep, primarily by reducing pre-sleep anxiety, stress, and loneliness, and by promoting a consistent sleep schedule. Similarly, a recent survey of 1,271 adult women indicated that dog owners had earlier and more consistent sleep and wake times, and that co-sleeping with dogs was associated with greater perceived comfort and security and fewer disruptions than sharing a bed with a human partner (Hoffman et al., 2018).

To date, few studies have examined pet-human co-sleeping using objective methods to quantify sleep measurement. Patel et al. (2017) used accelerometers to simultaneously assess sleep in 40 dog-human dyads; higher sleep efficiency and shorter wake after sleep onset were observed in dog owners whose dogs slept in the bedroom (but not on the bed) than in those who shared a bed with their dogs. People who did not sleep with a dog in their bed or bedroom were not included, precluding comparison. These results are somewhat consistent with findings from Smith, Browne, Mack, and Kontou's (2018) study with five dog-human dyads. Smith et al. found that dogs' movements predicted human movement, and humans were significantly more likely to be awake during their dogs' periods of wakefulness than when the dogs were inactive. However, despite these apparent sleep disruptions, the dog owners reported good sleep quality. This discrepancy between activity-based sleep disruptions (i.e., accelerometry) and subjective sleep parallels that observed in human co-sleeping; sharing a bed with a partner is associated with greater sleep satisfaction, but poorer sleep measured using actigraphy (Pankhurst & Home, 1994; Troxel, Robles, Hall, & Buysse, 2007). It is plausible that accelerometers detect bed partners' activity, giving a false impression of poor sleep when sharing a bed. In other words, these research findings raise the question whether methodological limitations due to mismeasurement of co-sleeping have biased "objective" accelerometry data.

Most research on pet-human relationships and co-sleeping has been conducted with adult samples, but the effects of pet companionship are likely present across the lifespan. Similar to adults, children report strong attachment to their pets and view them as a source of social support, affection, and comfort (Cassels, White, Gee, & Hughes, 2017; McNicholas & Collis, 2001). Pet ownership is particularly common among families with children, with up to 75% of school-aged children living in a household with a pet (Westgarth et al., 2010); however, little is known about the prevalence and impact of co-sleeping with pets in childhood. Hoedlmoser, Kloesch, Wiater, and Schabus (2010) found that nearly 30% of a sample of 8- to 11-year-old children shared a bed or bedroom with a pet. Sharing a bed or bedroom with pets was associated with nighttime awakenings, but it is unclear whether co-sleeping influences other sleep dimensions in children. There is also a notable absence of research using more objective forms of sleep assessment, such as actigraphy or polysomnography, to examine pet-child co-sleeping.

The aim of the present study was to examine the sleep of children and adolescents co-sleeping with a pet compared to those who never do. Previous studies in adults have yielded mixed results, suggesting that co-sleeping with pets may have differing effects on subjectively and objectively measured sleep. As such, the present study aimed to investigate the effect of co-sleeping with pets on children using self- and parent-report sleep measures and actigraphy.

Method

Study Sample

Children and adolescents aged 9 to 17 years participated in the larger Healthy Heart Project at Concordia University. Children and their parents were recruited using flyers posted in the surrounding neighbourhood and bookmarks distributed at schools approved by the English Montreal School Board. Youth with severe psychopathology or using medications known to interfere with cardiovascular or endocrine functioning were excluded. Participants provided informed consent and assent prior to beginning the study, and were compensated for their time. The study was approved by the Concordia University Research Ethics Board (# UH10000088).

Procedure

Children and their parents took part in two visits to the laboratory scheduled two weeks apart. During the first visit, they completed questionnaires on demographic information, household composition, sleep, and health. They were given a wrist accelerometer (Actiwatch 2; Philips Respironics, Inc., Murrysville PA) to wear for 14 days to record continuous measurement of movement and sleep. A daily sleep log adapted from the Consensus Sleep Diary (Carney et al., 2012) was completed during this two-week period. During the second visit, participants returned the accelerometer and sleep log,

Sleep Measures

Accelerometer data were scored in Actiware (Version 6) using a standardized protocol to yield sleep dimensions (e.g., sleep/wake times, sleep duration, sleep onset latency, wake after sleep onset, number of awakenings).

Sleep Timing. Children's sleep patterns were evaluated using self-reported bed- and wake times on school nights and weekends. Children recorded their daily bed and wake times using an adapted version of the Consensus Sleep Diary (Carney et al., 2012). The Children's

Sleep Habits Questionnaire (CSHQ; Owens, Spirito, & McGuinn, 2000) was used to measure parents' reports of their children's sleep timing. This 43-item measure assesses child sleep habits and disturbances (e.g., "What time does your child usually go to bed on week nights?"). Items are rated on a three-point scale from 0 ("rarely") to 2 ("usually"). The CSHQ has shown high internal consistency, test-retest reliability, and construct validity (Owens, Spirito, & McGuinn, 2000). Sleep and wake times were also derived from nightly actigraphy data by averaging the times across the entire 14-day study duration, as well as separately for school nights and weekends.

Sleep Duration. Child-reported sleep duration was calculated using bed- and wake-times recorded by the child in the sleep log. Parent-reported sleep duration was calculated using bed- and wake-times reported on the CSHQ. Actigraphy was used to measure the total number of minutes between sleep onset and final awakening. The average sleep duration was computed for the 14-day period, as well as separately for school nights and weekends.

Sleep Onset Latency. Children recorded the time spent trying to fall asleep on each day of the study in their daily diary. Parent-reported sleep onset latency was assessed using the CSHQ (e.g., "Child falls asleep within 20 minutes after going to bed"). Time to sleep onset was also measured using actigraphy. This was defined as the number of minutes between the child getting into bed to go to sleep (i.e. "lights out") and the beginning of sleep (i.e., first 30 sec epoch scored as sleep).

***Sleep Disruptions*.** Children responded to an item evaluating frequency of nighttime awakenings (e.g., "I wake up during the night") using a five-point rating scale ranging from 1 ("Never") to 5 ("Always"). Children recorded the time spent awake during the previous night (wake after sleep onset; WASO) on the daily sleep log. Parents reported their child's typical number of awakenings (e.g., "Child awakes once during the night") and WASO (e.g., "How many minutes is your child awake during the night?") on the CSHQ. For actigraphy, the number of awakenings was defined as the number of continuous 30 sec epochs of wake. Wake after sleep onset was defined as the total duration in minutes of these wake periods.

Weekend Oversleep. Weekend oversleep refers to the difference in total sleep duration between school and weekend nights (Jarrin, McGrath, & Drake, 2013). For child- and parent-report and actigraphy, sleep duration was calculated individually for school nights and weekends using reported bed- and wake-times. School night sleep duration was then subtracted from weekend sleep duration to yield weekend oversleep. Actigraphy data were similarly calculated.

Circadian Preference. Sleep midpoint was calculated using child- and parent-reported bed- and wake-times, as well as bed- and wake-times from actigraphy. Sleep midpoint refers to the midpoint between sleep onset and final awakening, and is associated with circadian timing and dim light melatonin onset (Di Millia et al., 2013). Chronotype was assessed using a 10-item version of the Morningness-Eveningness Questionnaire modified for use in children (Carskadon, Vieira, & Acebo, 1993). The 10-item version of the questionnaire demonstrated moderate internal consistency in our sample (Cronbach's α=.73). Children answered questions about preferred schedule and timing of activities (e.g., "When do you have the most energy to do your favorite things?") using four- and five-item rating scales, with higher scores indicating greater evening preference. (There is no accelometer proxy variable for circadian preference.)

Sleep Quality. Children rated their sleep quality on a scale from 1 ("very bad") to 10 ("very good"). Ratings of sleep quality are commonly used to evaluate subjective perceptions of feeling rested and satisfied with one's sleep (Dewald et al., 2010). Children also reported how frequently they had trouble sleeping on a five-point scale from 0 ("never") to 4 ("always"). (There is no accelometer proxy variable for subjective sleep quality.)

Co-Sleeping with Pets. Children answered a question assessing co-sleeping ("how often do you share your bed with your pet") in the past month. Responses were rated on a six-point scale from 1 ("never") to 6 ("always"). The children were divided into three groups based on frequency of co-sleeping: those who never co-slept with pets ("never"), those who sometimes co-slept with pets ("sometimes," "once in a while"), and those who frequently co-slept with pets ("quite often," "frequently," "always").

Statistical Analysis

Data were analyzed using SPSS version 24.0. Variables were inspected for normality and outliers. Scatterplots, frequency histograms, and descriptive statistics (means, standard deviations, minimum, maximum, skewness, kurtosis) were examined for all variables.
One-way analysis of variance (ANOVA) was used to compare sleep dimensions between the three groups. Hedges' *g* effect sizes were calculated for each comparison. We then computed 95% confidence intervals around the effect sizes. Additionally, we created narrower confidence intervals based on Glass's delta effect size computed using each group's variance. This was done

to provide a more conservative confidence interval, accounting for differing sample size and variance across groups.

Results

Children (*N*=244) were about half male (56.6%) and predominantly Caucasian (63.5%; Asian 5.3%; Black 5.3%; Latin American 3.3%; Aboriginal 1.6%; Other/Mixed 20.9%). The sample included youth aged 9 to 17 years with a mean age of 12.62 years (*SD*=2.03). Most parents had completed a university degree, and families had an average household income of $99K (CAD). The three groups were comparable with respect to demographics, presence of allergies and asthma, and sleeping arrangements. Sample characteristics are presented in Table 1.

The three co-sleeping groups were found to have comparable sleep profiles across self-report, parent-report, and actigraphy (see Table 2). The results of all one-way ANOVAs indicated there were no significant differences across the co-sleeping groups (omnibus testing) for any sleep dimension. Children displayed similar sleep duration regardless of co-sleeping frequency. Sleep onset latency values were also consistent across groups. Children who sometimes or frequently co-slept with pets experienced no more nighttime awakenings than those who never co-slept with pets, and spent no more time awake during the night. There were no differences observed in circadian preference, with all groups demonstrating similar sleep midpoint timing and MEQ scores. All children reported comparable sleep quality and difficulty sleeping. Although equivalence across groups cannot be determined, the Hedges' effect sizes and confidence intervals for each comparison were examined to further evaluate comparability of the co-sleeping groups. All confidence intervals (except two) included zero, providing additional support for the absence of observed group differences. Notably, the "sometimes" group reported lower sleep quality and greater difficulty sleeping compared to the "frequent" group. Relatedly, moderately high effects sizes (Hedges' g >0.4) were observed for these two exceptions.

Discussion

Co-sleeping with pets is highly prevalent, but little is known about its effect on children's sleep. Pets are commonly considered to be disruptive to sleep, but there are few studies to support this claim, and many pet owners perceive their pets as calming and beneficial to their sleep (Krahn et al., 2015). The aim of the present study was to evaluate the effect of co-sleeping with pets on children's sleep. We found that pets did not disrupt sleep, and, in fact, frequent co-sleepers showed similar sleep to those who never slept with pets. All groups were comparable across a comprehensive profile of sleep dimensions, regardless of assessment method by self- or parent-report or actigraphy, suggesting that co-sleeping with pets had little influence on sleep in this sample.

Although equivalence could not be formally tested, the sleep dimensions appeared to be similar across groups. There were no statistically significant differences between groups, and almost all effect size confidence intervals included zero. While the inclusion of zero within a confidence interval does not necessarily signify a lack of meaningful difference (Kline, 2013); given the lack of statistical significance, high similarity across sleep variables, and generally small effect sizes, it may be interpreted as additional evidence of comparability across groups. There were moderate effect sizes (>0.4) found for two self-reported variables between the sometimes and frequent co-sleeping groups. A more thorough evaluation of co-sleeping and its night-to-night consistency is a suggested area of focus for future studies.

Previous research using actigraphy-derived sleep among adults has demonstrated increased movement and nighttime awakenings among those who share their bed with their pets, but this was not observed in the present sample. This may be due to methodological differences as past studies assessed co-sleeping on a nightly basis (i.e., daily log to record whether pet slept in bed), collected data for fewer nights, restricted participation to dog owners, and did not include a control group (i.e., non-co-sleepers). Previous studies also failed to consider the potential influence of pets' activity on sleep assessment with actigraphy, as it is plausible that co-sleeping may have interfered with measurement. Alternatively, it is possible that co-sleeping with a pet is less disruptive to children than adults. This could be due to physical characteristics of the person and the sleep environment; adults are generally larger and occupy more space than children, and many adults share a bed with a partner in addition to their pets. The presence of a pet may be less intrusive to children who are smaller and have more space available in their beds. Others have suggested that pets play a unique role in children's social networks, and co-sleeping with pets likely has different motivations and functions during childhood and adolescence (i.e., reducing bedtime fears).

The present study investigated the influence of co-sleeping on several sleep dimensions, and found that co-sleeping did not adversely impact any particular dimension. Past studies have focused almost exclusively on sleep duration, nighttime awakenings, and sleep quality. In addition to these variables, we demonstrated that co-sleeping did not interfere with onset latency, timing, midpoint, or circadian preference. The robustness of the results across the comprehensive sleep assessment provides further support for comparability across co-sleeping groups. In other words, children who frequently, sometimes, or never slept with a pet had largely similar sleep patterns. These results imply that co-sleeping with pets did not cause more nighttime movement (i.e., accelerometer activity) and was not linked to children's or parents' perception of sleep.

While co-sleeping with pets did not seem to impair children's sleep, it is also important to note that no benefits were observed. Co-sleeping with pets appeared to be a neutral activity with no demonstrable impact on sleep. The effects of co-sleeping may vary across children, and it is possible that the practice may be positive or negative depending on strength of attachment to the pet, presence of anxiety or sleep problems, consistency of sleep routine, and pet breed and characteristics. Future studies should incorporate additional social and psychological variables to provide a more complete understanding of pet-human co-sleeping in children. Overall, co-sleeping with pets appears to be relatively harmless and unlikely to result in poor sleep in children; however, parents should consider their own child's needs and sleep habits before permitting pets in the bedroom at night.

Strengths and Limitations

This study had three limitations that warrant discussion. First, due to the cross-sectional design of the study, we could not examine causality in the relation between co-sleeping with pets and sleep quality. Second, a single item was used to assess pet ownership and co-sleeping with pets. Other variables, such as pet characteristics (e.g., breed/species, size) and psychological factors (e.g., attachment, internalizing symptoms), may influence co-sleeping between children and their pets. Additionally, it was not known if participants who reported "never" co-sleeping with pets were non-pet owners, or if they simply did not share a bed with their pets (i.e., pet slept in bedroom or elsewhere). There may be differences between pet owners who do not co-sleep with pets and children who do not have pets at all, but this could not be evaluated. Third, co-sleeping was measured as the frequency of sharing a bed with a pet in the previous month; consequently, we were unable to determine if participants shared their beds with their pets during the sleep assessment with actigraphy. Because data collection took place over a prolonged period of time (i.e., two weeks), it is likely that frequent co-sleepers shared their beds with pets during the study, but we did not know how often or on which nights this occurred. Future research should include nightly recording of co-sleeping and objective measurement of the pet's location (i.e. in or out of the bed) or proximity to the child. Finally, the use of actigraphy to complement self- and parent-reported sleep was a significant strength of this study. Using multiple assessment methods yields information about different aspects of sleep and sleep habits, and permitted a more comprehensive evaluation of comparability across co-sleeping groups.

Conclusion

This is the first study to examine pet-human co-sleeping in children using both subjective and activity-based measures of sleep. Children who shared their beds with their pets showed similar sleep profiles to those who did not, indicating that co-sleeping was neither harmful nor beneficial to sleep. These findings suggest that co-sleeping with pets may not be as disruptive as previously thought, and that it is unlikely to affect sleep in healthy children.

TRANSITION TO STUDY 2

The purpose of Study 1 was to compare the three co-sleeping groups of children and adolescents who varied in frequency of sharing a bed with their pet. Children who frequently and sometimes co-slept with pets were observed to have comparable sleep to those who never slept with a pet; and, this finding was consistent across multiple sleep dimensions and method of assessment (child-report, parent-report, and actigraphy). Study 1was the first investigation of pet-human co-sleeping among children (to the best of our knowledge), and included a larger sample size and more comprehensive sleep assessment than past studies in adults. These findings suggest that co-sleeping with pets is not as detrimental to sleep as previously thought, and is unlikely to harm sleep quality in healthy children.

While these findings are promising, they also raised several questions about co-sleeping and dyadic sleep measurement. Methodological limitations precluded more detailed examination of the possible effects of co-sleeping with pets. Specifically, similarly to previous studies in this area, Study 1 relied on self-report information to identify who shared a bed with their pet and frequency of co-sleeping. Children endorsed a single question to indicate how frequently they co-slept with pets in the past month. It was not known whether or when they co-slept with their pets during the accelerometry study. Other researchers have measured co-sleeping using a daily log; however, this method is still insufficient to adequately capture momentary co-sleeping patterns as pets often move around the home at night. Owners may notice that their pets were present at bedtime or upon awakening, but they are unlikely to be aware of their pet's location at all times overnight. Without knowing the pet's precise location, it is impossible to determine if pets disrupt their owner's sleep.

Additionally, Study 1 did not address the psychological aspects of co-sleeping with pets. Past research indicates that adults sleep with their pets because it is relaxing and reduces stress, but children's reasons for co-sleeping with pets are unknown. The decision to share a bed with a pet may be related to closeness or strength of the attachment relationship between the pet and person. Children who are more attached to their pets may be more likely to derive comfort or satisfaction from co-sleeping with them.

These limitations posed challenges in comparing sleep across groups, and raised novel questions about the methodology used in co-sleeping research. Thus, the goal of Study 2 was to conduct a proof-of-concept project that could better inform future co-sleeping research to assess dyadic sleep. The objectives of Study 2 were: (i) evaluating proximity measurement, (ii) evaluating simultaneous accelerometry in dyads, and (iii) testing psychometric assessment of one's attachment to pets.

Study 2:

Co-Sleeping Proof-of-Concept: Dyadic Sleep Measurement and Pet Attachment

Introduction

The field of sleep research has grown exponentially in recent decades as sleep has become increasingly recognized as a critical factor in health and psychological functioning. The area of co-sleeping, however, has stagnated due to numerous methodological challenges in dyadic sleep assessment. Although most people regularly share a bed with another being (spouse, child, pet), all current measurement tools and approaches were developed for individual use (i.e., solitary sleep). Past dyadic studies have attempted to apply these methods to co-sleeping, resulting in a body of research that is potentially flawed and inconclusive. To advance the field of co-sleeping research, it is necessary to develop more accurate and ecologically valid methods of sleep measurement, rather than relying on traditional methods that have been proven insufficient. This proof-of-concept project aimed to address these issues by evaluating new methods of assessing dyadic sleep, using pet-human dyads as a model of co-sleeping. Sequential experiments were conducted targeting three principal elements relevant to the study of co-sleeping: i) measurement of physical proximity between pets and owners, ii) dyadic sleep measurement using accelerometry, and iii) psychometric tools to measure attachment to pets.

Actigraphy is commonly used to measure sleep for research purposes, primarily due to its convenience, non-invasiveness, and relatively low cost. Comparisons with polysomnography (PSG), the gold-standard method of sleep assessment, suggest that actigraphy is able to adequately detect sleep and wake patterns (Kushida et al., 2001; Marino et al., 2013; Meltzer et al., 2012). However, while actigraphy appears to be a reliable and valid method of measuring sleep in individuals, its accuracy in co-sleeping contexts (e.g., people and pets, romantic bed partners, parents and children) has not been investigated. Studies of adult couples show discrepancies between actigraphy data and sleep assessed using self-report measures and using PSG, suggesting that co-sleeping may interfere with actigraphy. Similar findings have been observed in pet-human dyads; people display more actigraphy-derived movement when sharing a bed with their dogs, but report good sleep quality (Smith et al., 2018). Because actigraphy is fundamentally based on movement to estimate sleep dimensions, it is highly plausible that an actigraph could detect a bed partner's movement and yield inaccurate, invalid data indicating sleep disruption or wakefulness. It is also conceivable that a bed partner could mask sleep fragmentation by restraining movement of an accelerometer (i.e., arm tucked under person).

To better understand the source of movements and awakenings among co-sleepers, it is essential to simultaneously assess sleep for both members of the dyad using time-synchronized recordings of movement. For example, among pet owners who co-sleep with their pets, it is necessary to simultaneously assess both the person's and dog's activity using actigraphy. This will enable examination of the synced and lagged associations between the human and dog movements, which will lead to a more accurate assessment of influence of pets on humans' sleep. If the dogs' movements precede and are then closely followed by the human's movement, it is plausible (necessary, but not sufficient) that the dog's movement may be disrupting the person, causing her to move or wake up. If movement occurs at the same time for both the dog and person, this could indicate that one of the actigraphs is erroneously detecting the other's activity; alternatively, a third external stimulus could disrupt the sleep of both the dog and person (e.g., car alarm going off). Finally, if there are no synced, lagged, or simultaneous associations between their activity, it would imply that dog movement or activity does not affect the human's sleep as measured using actigraphy.

In addition to synchronized movement, it is also necessary to assess spatial proximity of the members of the dyad. While assessing both the person's and dog's sleep and activity is critical, in order to attribute false detection of movement the child and dog would need to be close to one another for one's accelerometer to capture the other's movement. In other words, to more precisely assess co-sleeping of the dyad, it is essential to determine that both are sharing the bed at a particular time of activity. Animals tend to follow different sleep-wake cycles than humans. It is likely that dogs wake up and leave the bed (and bedroom) during the night. Movement that occurs outside of the owner's bed, and especially movement occurring outside of the bedroom, cannot inadvertently move the wrist or waist accelerometer on the sleeping person. While it is possible that the dog's activity could still disrupt the person's sleep (i.e., running down hallway, scratching), when the dog is not in close proximity any movement detected is intrinsic to the human. Thus, improved co-sleeping methodology would likely benefit from assessment of dyad proximity. Failing to account for the dog's spatial location (relative to the owner) could influence the measurement or interpretation of the owner's sleep by giving a false impression of concordance/correlation if the human and dog's movements happen to correspond while the dog is absent. To more accurately isolate the sources of activity and sleep disruptions, it is necessary to know the dog's location relative to the child and to the bed.

EXPERIMENT A – Proximity Sensor Measurement

OpenBeacon proximity sensors use radio-frequency identification (RFID) technology. RFID systems fall within the broader category of automatic identification systems, which attach a name or identifier to a physical entity that can be automatically detected. While automatic identification systems can use optical, auditory, or even chemical identifiers, RFID relies on electromagnetic fields to transmit and receive identifying information. The basic functionality of RFID is identification; that is, sensors emit signals containing identifying information that can be detected by other sensors.

RFID sensors can be grouped based on function: Tags (i.e., transducers) carry identifying data. Each OpenBeacon sensor has a unique ID number that permits signals to be linked to specific sensors. Readers (i.e., transceivers) receive signals from tags. Readers communicate with tags through a radio-frequency channel to obtain identifying information. Each OpenBeacon sensor is programmed to act as both a tag and a reader. The sensor receives identifying information (e.g., unique ID number) from all other sensors within range of communication (6 meters), while simultaneously transmitting signals to the other sensors. The sensors function by collecting data several times per second. When the sensors collect data, they record the ID number of all other sensors emitting signals in close proximity, the distance between the tags (measured as received signal strength indicator; RSSI), and the elapsed recording time.

OpenBeacon sensors are active sensors, meaning that they each have their own source of power (i.e., battery-operated). This allows them to initiate communication with other sensors; they transmit signals that can be detected, without requiring the other sensor to query for information. These differ from other forms of RFID devices, such as semi-active sensors, which cannot initiate communication independently and only send signals when queried. OpenBeacon sensors have an operating frequency of 2.4 GHz, known as microwave or super-high frequency. This operating frequency permits higher sampling rates and more compact storage of data than lower frequency sensors. Super-high frequency sensors use more energy than low frequency sensors; however, they can be programmed to operate at a lower power if necessary.

Experiment A evaluated the measurement of location and spatial proximity of the pet owner, dog, and bed. Three methodological goals were to (1) establish the frequency of data collection, (2) determine the duration of battery life, and whether it was influenced by number of signals detected, and (3) test the relation between signal strength and proximity.

Experiment A.1 Data Sampling and Signal Detection

To test the frequency of data collection, OpenBeacon sensors were activated and placed in close proximity (5cm) in groups with one (paired), four (quintet), or nine (dectet) other sensors for a duration of 12 hours. After 12 hours, the data were examined for total number of recordings to verify sampling and signal detection.

It was expected that if signal detection was accurate, the paired sensors would detect one other sensor, those in quintets would detect four other sensors, and those in dectets would detect 9 other sensors. The frequency of data collected was unknown prior to testing, but it was expected that the number of signals detected would increase proportionally to the number of sensors present.

Data collected for Experiment A.1 are presented in Tables 3. As predicted, the number of sensor signals detected depended on the number of other active sensors present. Paired sensors detected an average of .75 signals per second. Quintet sensors detected an average of 1.86 signals per second (Table 4). Dectet sensors detected an average of 3.05 signals per second (Table 5).

It was observed that the sensors did not reliably collect data, and intermittently yielded an empty recording (i.e., blank data file). The reason underlying this recording error could not be resolved; all sensors appeared to be functioning (e.g., lights blinking) and were successfully transmitting signals (detected by the other sensors). Super-high frequency sensors are vulnerable to external interference. All tests were conducted in the same location, so the presence of metal or concrete did not vary, but there may have been other signals present (e.g., Wi-Fi, microwave) that obstructed the signals.

Experiment A.2 Battery Life

The battery life of the Open Beacon sensors is not specified by the manufacturers, but it was critical to know the duration of the battery life before deploying the sensors with research participants. To accurately detect patterns of proximity, and to use the sensors in conjunction with accelerometers, a battery life of at least five to seven days is required. Additionally, it is possible that the number of other sensors present may affect battery life.

Battery life, as a proxy for total recording time, was tested in single sensors, pairs of sensors, and groups of five sensors. If each signal detection uses power, it was thought that the battery life of the single sensors would be longer than the paired and quintet sensors. Sensors were placed in a fixed location and monitored daily to determine whether they were still collecting data (i.e., battery still charged). After the batteries had died, the data were examined. The initial goal was to examine the total recording time to determine the battery life.

Sample data for Experiment A.2 are presented in Table 4. Upon inspection of the recordings, data became uninterpretable over the duration of the experiment. Recording time was measured as the number of seconds elapsed since the start of recording. As recording progressed, the time of recording became highly inaccurate for all 15 sensors. On average, this began after 52 hours, or slightly more than two days of recording (*M*=51.8 hrs, *SD* = 10.77). For the remaining days of data collection, the sensors alternated between providing plausible data and erroneous recording times (e.g., 1,892,220,930 seconds, or 60 years). Additionally, the sensors all began recording signals from sensors that did not exist (e.g., 0xD4000094, 0xCA000094), which coincided with the inaccurate recording times. Yet, inaccurate recording times were not always accompanied by an incorrect signal detection, however.

Of the 15 sensors tested, 14 restarted recording multiple times, resetting the recording time to zero. This occurred between zero (i.e., no restart) and 108 times, with an average of approximately 41 times (*M*=40.67, *SD*=36.77). The average time to first restarting could not be computed as the recording time data often became corrupted before the recording had reset. Recordings restarted sporadically, and it appeared to increase in frequency over time, but the inaccurate time data prevented further evaluation.

Because of these issues with data collection, the exact duration of battery life could not be determined. The sensors were examined every 24 hours to determine if they were still recording (i.e., light blinking) or if the battery had died. Based on this daily monitoring, it appeared that the battery life was approximately 7 days regardless of the number of sensors present, but the state of the data precluded more precise examination. For future studies, it is recommended that the OpenBeacon sensors be used with caution up to approximately 50 hours; the data do not support use beyond this point.

Experiment A.3 Signal Strength and Proximity

OpenBeacon sensors use the received signal strength indicator (RSSI) as a measure of the proximity between sensors. RSSI indicates the power present in a received radio signal. RSSI is typically presented as a negative number, with numbers closer to zero indicating a stronger signal. RSSI has frequently been used in experiments to estimate position and distance; however, it is prone to interference from numerous environmental variables when used indoors, including walls, furniture, people, humidity, metal, water, and Wi-Fi signals. Findings on its reliability and accuracy are inconclusive, and it remains unclear whether RSSI is an appropriate method of quantifying proximity.

The goal of this section was to quantify the relation between RSSI and distance between the sensors. Three experiments were conducted testing horizontal proximity, vertical proximity, and potential obstruction of the signals by materials commonly found in bedrooms. Both horizontal and vertical proximity were tested as OpenBeacon sensors were originally designed for face-to-face contact; it was not clear whether positioning of sensors above, below, or to the side of one another would affect signal detection.

All experiments were conducted with 5 pairs of sensors. Experiments were performed separately for each sensor pair, in the absence of other sensors.

Horizontal and Vertical Proximity. To test horizontal proximity, sensors were initially placed on a flat surface (wooden floor) adjacent to one another, with no distance separating them. After three minutes elapsed, one sensor was moved away from the start point in 30cm increments across a distance of 3m, while the other sensor remained stationary. The movements occurred in a horizontal plane, in a straight line without lifting the sensor from the surface. Following each 30cm movement, the sensor remained in place for three minutes to permit adequate recording of its position.

To test vertical proximity, the sensors were initially positioned with no distance separating them. After three minutes elapsed, one sensor was moved vertically from the start point in 30cm increments across a distance of 2.4m. The moving sensor was held at a 90-degree angle to the stationary sensor, and was moved in a straight line across a perpendicular surface (wall) without lifting the sensor. Following each movement, the sensor remained in place for three minutes.

RSSI and distance are presented for each pair in Figure 1 (horizontal proximity) and Figure 2 (vertical proximity). The relation between RSSI and distance appeared to be linear. For horizontal proximity, the initial RSSI value was about -45 when the sensors were in close proximity (i.e., adjacent) and decreased to approximately -85 to -90 when 3m apart. For vertical proximity, the initial RSSI value was approximately -45 and decreased to approximately -85 when 2.4m apart. Change in distance did not always correspond to consistent changes in RSSI values, but a general reduction in signal strength was evident as distance increased between the sensors. For both horizontal and vertical proximity, one of the five sensor pairs did not demonstrate any significant changes in RSSI. This occurred in different pairs for each experiment, so the signal transmission may have been impact by environmental factors or low battery power.

Signal Obstruction. Proximity measurement was evaluated in the presence of four potentially disruptive materials commonly found in bedrooms and homes. Five sensor pairs were used to test each material. Tests were conducted separately for each pair, in the absence of other sensors. Following experiments with each material, the number of recordings and signal strength were examined and compared with data collected with no obstructions. Mean RSSI values and number of signals detected are presented in Table 5.

Metal. Sensors were placed on a metal bedframe for five minutes. The sensors were positioned 30cm apart and attached to the bedframe using string. The metal bedframe did not interfere with data collection. Sensors detected an average of .75 signals per second and had an average RSSI of -44.7, similar to recordings at 30cm with no obstruction.

Thin Fabric. Sensors were placed 30cm apart on a flat surface (wooden floor) for five minutes with a bedsheet separating them. Results indicated that the sheet did not interfere with the signal. Sensors detected an average of .75 signals per second and had an average RSSI of -49.3.

Thick Fabric. Sensors were placed 30cm apart on a flat surface (wooden floor) for five minutes with a fleece blanket separating them. The sensors detected each other despite the blanket, indicating that it did not interfere with measurement. Sensors detected an average of .76 signals per second and had an average RSSI of -47.8.

Wood. Sensors were placed 30cm apart on a flat surface for five minutes with a wooden door separating them. The door did not obstruct the signals and the sensors were able to communicate. Sensors detected an average of .76 signals per second and had an average RSSI of -52.3.

EXPERIMENT B – Dyadic Sleep Measurement and Proximity

EXPERIMENT B.1- Measurement of Co-Sleeping

The goal of experiment B.1 was to test dyadic measurement techniques in pet-human dyads. Dog owners and their pet dogs were recruited to wear proximity sensors and accelerometers, and completed a series of questionnaires assessing attachment to pets.

Study Sample

A convenience sample of seven dog-human dyads were recruited to participate. Characteristics of the dogs and humans are presented in Table 9. Participation was limited to dogs as dog owners report strong attachment to their pets and dogs are more likely to habituate to their owners' sleep patterns than other animals. Participants provided informed consent and assent prior to beginning the study. The study was approved by the Concordia University Research Ethics Board (#10000088).

Materials & Measures

Human activity and sleep. Human activity was measured using the Actiwatch 2 (Philips Respironics). Data were scored in Actiware software using a standardized protocol to yield sleep dimensions based on activity level and light. Detailed information about scoring accelerometer data follows in the section below. Participants also recorded their sleep timing, nighttime awakenings, sleep quality, and co-sleeping using an adapted form of the Consensus Sleep Diary (Carney et al., 2012).

Dog activity. Dogs' activity patterns were measured using the Actical (Philips Respironics). Scoring procedures are described in detail below.

Proximity. Proximity between humans, dogs, and specific locations in the home was measured using the Open Beacon proximity sensors (described in detail in Experiment A.1).

Procedure

Participants took part in two visits to the laboratory scheduled approximately one week apart. During the first visit, they completed a brief questionnaire on demographic information and pet ownership and were given devices to wear.

Five participants were given a wrist accelerometer (Actiwatch 2) to wear on their nondominant arm at all times for five consecutive days. They also received an accelerometer (Actical) to attach to their dogs' collars for five days. The method of attachment varied depending on dog size and collar type; participants were given the option of attaching the accelerometer without a case, placing the accelerometer inside a metal case, attaching the accelerometer to the dog's own collar, or using a collar provided by the researcher. Participants kept a daily sleep log during the five-day period. Additionally, participants completed a different measure of attachment (described in next section) on each of the five days. The order of attachment questionnaire completion was randomized across participants.

The remaining two participants each received four proximity sensors. They were each given one sensor to wear on their wrists at all times for five days. They also received a sensor to attach to their dogs' collars during this period. Two additional sensors were provided to be placed in the home; they were instructed to place one sensor on or near their beds, and the other in a location that the dog was likely to visit during the night (e.g., dog bed, crate, food). Participants kept a daily sleep log and completed the different daily attachment measures (random order) during the five-day interval.

During the second visit, participants returned the devices and questionnaires. They were also asked to provide qualitative feedback on their experience with the devices, their dogs' behaviour during the study, and any concerns or issues noted during their participation.

Human and dog characteristics of the convenience sample are presented in Table 6. Pet owners were all female and had a mean age of 30.29 years. Dogs were predominantly male, varied in size and breed, and had a mean age of 6.08 years. Duration of ownership ranged from several months to 11 years, with a mean of 5.15 years.

Human and Canine Accelerometry

Examination of the humans' and dogs' accelerometer data revealed many similarities. The devices were configured to have the same epoch length (30s) to facilitate data comparison. Both human and canine data illustrated trends in movement over the five-day period, as well as the level of movement occurring during any given epoch. Five-day patterns in activity counts are presented in Figure 3.

Actigraphy Scoring

The Actiwatch 2 worn by the humans is designed to measure sleep and activity. Specialized scoring software (Actiware®) combined with manual editing is used to derive sleep dimensions, taking into account activity level, light, and presence of event markers (button used to indicate bed and wake times). This scoring protocol has been previously validated (McGrath, Noel, & Burdayron, 2018). Conversely, the Actical worn by the dogs is primarily an activity monitor. The Actical software does not provide an algorithm to score sleep and wake patterns, and instead measures frequency, duration, and intensity of activity. Data generated by the scoring software include activity counts, classification of activity counts into sedentary, light, moderate, or vigorous, and percentage of time spent in activity of varying intensities.

Because the Actiwatch 2 and Actical are produced by the same company and can be programmed to record data using the same parameters, data from the dogs' Actical can be imported into Actiware to analyze dogs’ sleep. However, the activity patterns are analyzed using human algorithms; there are no existing algorithms or scoring protocols specifically for dogs. In a prior study, Zanghi et al. (2013) also used the Actiwatch 2 to measure dogs’ sleep. They used the manufacturer’s human scoring approach to estimate dogs’ sleep; however, this may not be appropriate given that the scoring algorithms were developed and validated for humans. Sleep patterns vary considerably between species, and the same activity thresholds and sleep dimensions may not be relevant for non-human animals.

There is limited research on canine sleep patterns. In the context of pet-human co-sleeping, it may be more useful simply to consider whether the dog is active or not at a given moment (i.e., awake for 30s epoch). For future co-sleeping research, the dog’s sleep dimensions may not be as relevant as the effect of the dog’s movements on human sleep. In other words, it is not essential to quantify or understand the dog’s sleep quality or disturbances. Further, while it is not clear what activity level (i.e., frequency count) constitutes “active” compared to “inactive”, within-dog variability and magnitude of activity relative to the human-dyad counterpart is relevant. One simple approach is to score dogs’ activity level using human algorithms, and to categorize any epoch scored as “wake” as a period of activity for the dog. Future co-sleeping research may benefit from establishing normative data for activity levels for dogs and developing sleep algorithm thresholds based on these values.

Table 7 presents the average activity counts, average activity counts scored as sedentary, light, moderate or vigorous activity, and the average percentage of time spent in each of these activity levels by the dogs in this study. Findings were comparable to those previously observed by Michel and Brown (2014), who measured activity in 98 dogs of varying breeds and sizes over a two-week period.

Participants experienced few issues with the canine accelerometers. One participant reported that her dog initially scratched her neck when the the accelerometer was attached to the collar, but this subsided quickly. No other behavioural concerns were noted. Several dyads experienced problems attaching the accelerometers to the collar. Participants with larger dogs (i.e., heavier than about 45 pounds) were provided with metal cases to protect the accelerometers and to facilitate attachment to thick collars. However, even with the case, most dogs’ collars were too thick or had large buckles that interfered with attachment. Two participants chose to borrow a thin collar from the researcher, which the dogs wore above their regular collars. This allowed them to wear the accelerometers, but may have caused discomfort from wearing two collars simultaneously. Two other participants chose to secure the accelerometers using zip ties or string, but experienced issues with the accelerometers remaining attached for the duration of the study. The fifth dog was much smaller than the others (under 10 pounds) so the case and collar provided by the researcher were too large. The owner chose to tie the accelerometer to the dog's collar without using a case, and experienced no further issues. However, the accelerometer was unprotected and could have been damaged by activity, water, or detachment. For any future studies, new protective cases should be designed to accommodate diverse dog sizes and collar types.

Analysis of Dyadic Sleep

Co-sleeping research has been greatly limited by a lack of knowledge regarding analytic techniques to evaluate dyadic sleep. Rather than examining the synchronized or lagged between partners' sleep patterns, most previous studies focused exclusively on one partner's sleep, or only included subjective sleep. The use of actigraphy or polysomnography in dyads poses compelling challenges due to the complexity of psychophysiological data. Several past studies examined concordance in bed partners' sleep by computing the percentage of epochs (i.e., short segment of actigraphy data that is scored as wake or sleep) in which both partners were either asleep or awake (Gunn et al., 2015; Pankhurst & Horne, 1994). This gross technique is useful in determining whether bed partners have similar sleep patterns, but cannot be used to investigate the causal effects of co-sleeping on each partner's sleep. Furthermore, this analytic approach fails to capture dynamic change in sleep patterns across the night.

Brown et al. (2018) took a similar gross percentage approach to assessing co-sleeping in humans and dogs; and, they also performed cross-correlation analyses to evaluate potential relations between the dogs' and humans' actigraphy data. Cross-correlation is a form of time-series analysis which evaluates the similarity of two data series as a function of a time-lag applied to one of the series. Brown et al. (2018) applied time-lags of 30 seconds and 2.5 minutes to dogs' movement and considered these as potential predictors of human movement and sleep/wake state; they found that for both lags, dogs' movements significantly predicted both movement and wakefulness in humans. Cross-correlation analyses have been previously used to examine other psychophysiological signals in dyads, including maternal and fetal heart rate (Dipietro, Irizarry, Costigan, & Gurewitsch, 2004), and respiratory sinus arrhythmia (RSA) in married couples (Gates, Gazette-Kopp, Sandsten, & Blandon, 2015). Due to the small sample size and exploratory nature of this pilot test, the relationbetween human and dog movement were not evaluated. However, the cross-correlation method used by Brown et al. (2018) is a promising approach for analyzing these data.

Proximity of Pets and Owners

Of the eight OpenBeacon sensors deployed (four per dyad), two produced blank data files. The remaining six collected data for the duration of the study. All six sensors transmitted signals and were detected by the other sensors. RSSI values fluctuated over the course of the study, ranging from -49 to -70. Data recording typically began resetting approximately 9 hours into data collection; this was much sooner than the 52 hours observed in Experiment A.1. The sensors restarted between 18 and 138 times. Due to inaccurate time values and repeated clock resetting during data collection, the sensors could not be time synchronized. Thus, it was impossible to draw meaningful conclusions about the proximity of the pets, owners, or other sensors. Ultimately, this degradation of data quality over the five-day period prevented investigation of any patterns in the data.

Although Open Beacon sensors have been successfully used to measure face-to-face contact over short periods of time (i.e., 24 hours) in others' social network analyses, they do not appear to be sufficiently developed to measure proximity or contact time in less structured, more naturalistic settings. The recording was often imprecise and appeared to be influenced by environmental factors and technical malfunctions that could not be predicted. Further, proof-of-concept testing indicated that the sensors only recorded useable data for a short period of time (i.e., between 9 and 52 hours) before the quality begins to decline. Consequently, at this time it is not recommended to use the proximity sensors in conjunction with actigraphy over a one- or two-week period, as long-term trends in pet-human contact could not be accurately or consistently examined. The use of proximity sensors remains a novel idea in the assessment of pet-human relationships and co-sleeping, but the current OpenBeacon sensor technology was deemed insufficient for our research needs and requires considerable refinement.

EXPERIMENT B.2 – Attachment to Pets

Previous studies of pet-human co-sleeping have primarily focused on sleep disturbances and sleep quality, neglecting other social and psychological factors that may be involved. The level of attachment to pets is likely relevant for co-sleeping, and may determine whether co-sleeping with a pet is disruptive or beneficial. For example, people with strong, secure attachment to their pets likely derive comfort from sleeping with pets, while those with a weaker attachment may experience sleep disruption. This is parallel to empirical observations in marital relationships; sleeping with a partner seems to be less disruptive for couples with closer relationships (Troxel et al., 2009). Attachment may also explain why many individuals with allergies or respiratory problems (e.g, asthma) still choose to sleep with their pets (Krahn et al., 2015).

To complement assessment using accelerometry and proximity sensors, participants from the previous proof-of-concept study completed five different measures of attachment (random order) over a five-day period. The measures were personalized to include their pets' names (e.g., "Rover greets you at the door when you get home."). The questionnaires are described below.

Lexington Attachment to Pets Survey (LAPS). The LAPS is a 23-item questionnaire assessing comfort derived from pets, closeness of pets and owners, and perceptions of pet-human relationships. Respondents rate items on a four-point Likert scale ranging from 0 ("strongly disagree") to 3 ("strongly agree"). Items are added to provide a total score ranging from 0 to 69. Higher scores indicate stronger attachment. The LAPS is perhaps the most commonly used measure of attachment to pets, and has shown excellent internal consistency (α = .90 to .99; Daly & Morton, 2006; Johnson et al., 1992).

Pet Attachment Questionnaire. The Pet Attachment Questionnaire (PAQ; Zilcha-Mano, Mikulincer, & Shaver, 2011) consists of 26 items designed to measure attachment anxiety and avoidance in relationships with pets. Items are rated on a seven-point Likert scale from 1 ("disagree strongly") to 7 ("agree strongly"). Item ratings are summed to yield a total score, as well as two subscale scores: avoidance (i.e., reluctance to be close to pet, lack of emotional attachment) and anxiety (i.e., insecurity in relationship with pet). Total scores can range from 26 to 182, with subscale scores ranging from 13 to 91. Higher scores indicate a greater degree of attachment insecurity and avoidance. The PAQ has shown good internal consistency (α = .86 to .89) and moderate test-retest reliability (r = .75 to .80; Zilcha-Mano et al., 2011).

Pet Attachment Survey. The Pet Attachment Survey (PAS; Holcomb et al., 1985) consists of 27 items classified into two subscales: relationship maintenance (i.e., interaction, communication, time spent with pet) and intimacy (i.e., proximity, emotional closeness).

Responses are rated on a four-point Likert scale from 1 ("almost never") to 4 ("almost always"). Scores range from 27 to 108, with subscale scores ranging from 16 to 64 for relationship maintenance and 11 to 44 for intimacy. Higher scores indicate greater attachment. The PAS has demonstrated acceptable internal consistency (α=.74 to .83; Holcomb et al., 1985).

Pet Relationship Scale (PRS). The Pet Relationship Scale (PRS; Kafer, Lago, Wamboldt, & Harrington, 1992) is a 21-item measuring attachment to pets and activities performed within pet-human relationships. Respondents rate items on a four-point Likert scale from 0 ("strongly disagree") and 3 ("strongly agree"). Item ratings are added to obtain a total score ranging from 0 to 84, with higher scores indicating stronger attachment. The items are divided into three categories: affectionate companionship (i.e., time spent with pet), equal family member status (i.e., treatment of pet), and mutual physical activity (i.e., activities performed with pet). Each subscale contains 7 items and has a maximum score of 21. The PRS has been used infrequently in research, and has less established psychometric properties than the LAPS, PAS, or PAQ.

Inventory of Pet Attachment. The Inventory of Pet Attachment (IPA; Andrews, 1992) is a 35-item measure evaluating emotional closeness and attachment to pets. Items are rated on a seven-point Likert scale from 1 ("completely false") to 7 ("completely true"). Total scores range from 0 to 245, with higher scores suggesting greater attachment. The IPA was developed as part of an unpublished doctoral dissertation, and has not been used in previous published research. Little is known about its psychometrics or utility.

Mean scores and standard deviations for total and subscale scores are presented in Table 8. The attachment measures had variable internal consistency in this small sample (see Table 12). Internal consistency was reasonably high for the Pet Attachment Questionnaire (α=.809) and excellent for the Inventory of Pet Attachment (α=.948) and Lexington Attachment to Pets Scale (α=.910). The Pet Relationship Scale (α = .445) and Pet Attachment Survey (α=.349) had low internal consistency. Given the very small sample size for this trial of the measures, these values may not be representative and should be interpreted with caution

To evaluate covariance among the measures of pet attachment, Pearson correlation coefficients were computed (see Table 9). None of the correlations between total scores were statistically significant; however, this is likely due to the sample size. Several moderate to strong correlations (r=.338 to .915) were observed between total scores and subscale scores on the

Lexington Attachment to Pets Scale, Pet Attachment Survey, Pet Relationship Scale, and Inventory of Pet Attachment. The strongest correlations were observed between the Inventory of Pet Attachment and the Pet Relationship Scale and Lexington Attachment to Pets Scale. This likely reflects the similarity of the constructs measured. These three questionnaires focus on feelings of attachment, viewing pets as family members, preferring pets to other people, and pets contributing to positive mood, among other items. While the Pet Attachment Survey contains similar items, it has a strong emphasis on physical proximity or closeness. This may explain the moderate negative correlations ($r= -.592$ to $-.748$) between the Pet Attachment Survey intimacy subscore and scores on the Pet Attachment Questionnaire. The intimacy subscale assesses desire for closeness to pets in various contexts; given that the Pet Attachment Questionnaire measures avoidance and anxiety around one's pet, it is not surprising that these measures are negatively correlated. Moderate negative correlations ($r= -.321$ to $-.664$) were also observed between the Pet Attachment Questionnaire scores and other measures (Lexington Attachment to Pets Scale, Pet Relationship Scale). These findings provide preliminary evidence for correlations between measures of positive attachment (i.e., Lexington Attachment to Pets Scale, Pet Attachment Survey, Pet Relationship Scale, Inventory of Pet Attachment), and negative correlations between the Pet Attachment Questionnaire and the other measures. These trends may be more evident in a larger sample size and should be investigated further. It also appears that there is some disagreement in defining the attachment to pets. While the positive attachment measures contained many similar items, the measures had different areas of focus. In the future, it may be helpful to identify which constructs are most relevant to pet relationships.

These attachment measures have been used infrequently in research and there is no clear preferred or "gold standard" measure of attachment to pets. Consequently, study participants were asked to qualitatively comment on the measures in order to guide instrument choice in future research. The Pet Attachment Questionnaire was the most widely criticized measure by study participants. Participants reported that the questions were not effective in evaluating pet-human relationships, and were more appropriate for romantic relationships. Furthermore, most respondents reported strong attachment to their pets, and the Pet Attachment Questionnaire items were not applicable to their relationships due to the focus on anxiety and avoidance of contact. Most participants scored quite low on this measure, suggesting that it is not a useful measure for pet owners who report healthy attachment to their pets. The other four measures were generally well-received by participants, and comments generally involved minor issues with wording or content of specific items. Participants noted ambiguously or strongly worded items on the Lexington Attachment to Pets Scale (e.g. "My pet means more to me than *any* of my friends") and Pet Relationship Scale (e.g., "I treat my pet to anything I happen to be eating"). Participants also reported that they disagreed with certain items, such as referring to pets as "valuable possessions on the Pet Attachment Survey, or the reasons for loving one's pets provided on the Lexington Attachment to Pets Scale (e.g. because he/she never judges me" or "because he/she is more loyal to me than most of the people in my life"). Certain measures were deemed more appropriate in certain contexts or living arrangements. For example, the PAS appears to be designed for respondents living with families, and since most participants lived alone, they found that several items were difficult to answer because they assessed pets' relationships with and preference of different household members. Similarly, it was noted that the Inventory of Pet Attachment is appropriate for adults, but includes many items that are not relevant to children, such as spending money on pets, planning for pets' deaths, and making provisions for pets in one's will. While this was not an issue in the current sample, the ultimate goal is to investigate pet-human co-sleeping in children and adolescents.

Conclusion

This proof-of-concept project was designed to evaluate methods of assessing co-sleeping with pets, as well as the measurement of relevant covariates such as attachment. The primary goals of this project were to explore measurement of physical proximity between pets and owners, test dyadic sleep measurement using accelerometry, and evaluate psychometric tools to measure attachment to pets.

OpenBeacon proximity sensors were tested as a way of verifying pets' location when using accelerometers to measure co-sleeping. These sensors were found to collect data unreliably, and data quality was highly variable depending on the duration of use. Due to these issues, data collected from dog-human dyads was uninterpretable and could not be used to examine their patterns of proximity and contact over a five-day period. At present, the sensors are not sufficiently developed for dyadic sleep assessment. In order to be useful in this line of research, the OpenBeacon sensors need to improve battery life and reliability of data collection. The methods proposed in this thesis could lead to an advancement in the assessment of co-sleeping when applied to more developed and precise measurement devices. Actigraphs have recently been developed that include Bluetooth capability, so this could be an interesting option for further studies. For example, the ActiGraph wGT3X-BT has been used to measure parent-child proximity over a one-week period (Kuzik & Carson, 2018). Additionally, proximity in bed might be best captured using devices on the bed, rather than wearable sensors. For example, mattress pads that detect movement or produce a heat map of the pets' and owners' location may be a promising avenue for future research.

Accelerometry in dog-human dyads indicates there are similarities in the data produced by pet-human dyads. When accelerometry is used simultaneously in dyads, the dogs and humans provide comparable activity data that can be time-synchronized and analyzed. Currently, there are no scoring algorithms designed for dogs' accelerometry data, and it is not known how best to score their sleep and wake patterns. Future research should focus on establishing normative canine activity and sleep values to inform the development of scoring approaches for canine activity.

Evaluation of pet attachment measures yielded mixed findings. Few studies have used these measures, and their utility and psychometric properties are largely unknown. The questionnaires were well-received in general, but participants noted several issues with content and test construction for all measures that were tested. In the future, it may be useful to conduct an item-level analysis of attachment measures to inform the development of more rigorous assessment tools that better capture the construct of attachment to pets. Furthermore, few of the existing attachment measures have been used in children, and additional research is needed to develop and validate measures that are relevant for younger participants.

GENERAL CONCLUSION

Pets are highly valued by their owners. Both child and adult pet owners report strong social bonds with their pets, and many view their relationships with their pets as similar to human relationships. It is common for pet owners to share a bed with their pets, but few studies have examined the impact of co-sleeping on humans' sleep. Past studies have yielded inconsistent results due to small sample sizes and lack of appropriate controls. To date, there have been no studies of pet-human co-sleeping in childhood, despite the fact that families with children are more likely to own pets than any other demographic.

The overarching goal of this research was to improve our knowledge of co-sleeping among humans and pets. Specifically, my thesis focused on the effects of co-sleeping with pets on children's sleep. A secondary aim of this thesis was to investigate preliminary methods of assessing co-sleeping and analyzing dyadic sleep data. My thesis was divided into two projects addressing these objectives.

Study 1 examined sleep dimensions and sleep quality in youth who co-slept with pets and those who did not. Sleep was found to be comparable across groups, and this was consistent across all sleep dimensions and multiple methods of measurement. Although co-sleeping with pets has been previously discouraged by health professionals, these findings suggest that children who co-sleep with pets experience no more sleep disruptions than children who sleep alone.

Study 2 focused on optimizing methods for measuring pet-human co-sleeping. This proof-of-concept project involved tests of proximity measurement, dyadic measurement of sleep and proximity, and attachment to pets. The results of these preliminary tests and experiments yielded valuable information on conducting research on pet-human dyads. Simultaneous use of accelerometry appears to be a viable method of assessing sleep in pet-human dyads. However, proximity measurement is not sufficiently advanced to permit quantification of pets' proximity to their owners. These findings provide a critical first step for further studies in this population, and will guide the future development of assessment methods and measures.

Overall, the findings from this thesis represent an original contribution in the area of pet-human co-sleeping. This was the first study to investigate pet-human co-sleeping in children and adolescents, and the findings suggest that co-sleeping with pets is not disruptive or detrimental to sleep in healthy children. Additionally, my thesis investigated dyadic accelerometry and the complementary measurement of proximity to more precisely quantify co-sleeping. Although proximity sensor technology is still in the preliminary stages of development, it presents a novel approach to addressing some of the methodological limitations and challenges of studying co-sleeping in pets and humans. At present, this method is not adequately developed to measure long-term patterns of pet-human proximity, and further refinement is necessary before it can be used in research. By taking this first step to advance measurement of co-sleeping, this proof-of-concept study provided a foundation for more refined and precise methodology to quantify co-sleeping in both human and non-human dyads. Finally, future research should incorporate attachment to pets when conducting co-sleeping research. Sleep is an important social context, and the strength of the attachment relationship likely plays a role in the relation between sleep quality and co-sleeping with pets.

References

Allen, K., Blascovich, J., & Mendes, W. B. (2002). Cardiovascular reactivity and the presence of pets, friends, and spouses: The truth about cats and dogs. *Psychosomatic Medicine, 64*(5), 727-739. doi: 0033-3174/02/6405-0727

Allen, K., Shykoff, B. E., & Izzo Jr, J. L. (2001). Pet ownership, but not ACE inhibitor therapy, blunts home blood pressure responses to mental stress. *Hypertension*, *38*(4), 815-820.

Andrews, S.L. (1992). *The inventory of pet attachment: Development and validation.* (Unpublished doctoral dissertation). Texas A&M University, College Station, USA.

Beninati, W., Harris, C. D., Herold, D. L., & Shepard Jr, J. W. (1999). The effect of snoring and obstructive sleep apnea on the sleep quality of bed partners. *Mayo Clinic Proceedings, 74*(10), 955-958.

Bloom, H.G., Ahmed, I., Ancoli-Israel, S., Buysse, D.J., Kryger, M.H., Phillips, B.A., Thorpy, M.J., Vitiello, M.V., & Zee, P.C. (2009). Evidence-based recommendations for the assessment and management of sleep disorders in older persons. *Journal of the American Geriatrics Society, 57*(5), 761-789.

Brown, C., Wang, T., & Carr, E. (2018). Undercover dogs: Pet dogs in the sleep environment of patients with chronic pain. *Social Sciences, 7*(9), 157.

Buysse, D. J., Reynolds III, C. F., Monk, T. H., Berman, S. R., & Kupfer, D. J. (1989). The Pittsburgh Sleep Quality Index: a new instrument for psychiatric practice and research. *Psychiatry Research*, *28*(2), 193-213.

Carney, C. E., Buysse, D.J., Ancoli-Israel, S., Edinger, J.D., Krystal, A.D., Lichstein,K.L., & Morin, C.M. (2012). The consensus sleep diary: Standardizing prospective sleep monitoring. *Sleep, 35*(2), 287-302.

Carpenter, J. S., & Andrykowski, M. A. (1998). Psychometric evaluation of the Pittsburgh sleep quality index. *Journal of Psychosomatic Research*, *45*(1), 5-13.

Carskadon, M.A., Vieira, C., & Acebo, C. (1993). Association between puberty and delated phase preference. *Sleep, 16*(3), 258-262.

Cohen, S., Doyle, W. J., Skoner, D. P., Rabin, B. S., & Gwaltney Jr., J. M. (1997). Social ties and susceptibility to the common cold. *The Journal of the American Medical Association, 277*(24), 1940-1944.

Cortesi, F., Giannotti, F., Sebastiani, T., Vagnoni, C., & Marioni, P. (2008). Cosleeping versus solitary sleeping in children with bedtime problems: child emotional problems and parental distress. *Behavioral Sleep Medicine*, *6*(2), 89-105.

Crowley, S. J., Acebo, C., & Carskadon, M. A. (2007). Sleep, circadian rhythms, and delayed phase in adolescence. *Sleep Medicine*, *8*(6), 602-612.

Daly, B., & Morton, L. L. (2006). An investigation of human-animal interactions and empathy as related to pet preference, ownership, attachment, and attitudes in children. *Anthrozoös*, *19*(2), 113-127.

Dewald, J.F., Meijer, A.M., Oort, F.J., Kerkhof, G.A., & Bogels, S.M. (2010). The influence of sleep quality, sleep duration and sleepiness on school performance in children and adolescents: A meta-analytic review. *Sleep Medicine Reviews, 14*(3), 179-189.

Di Milia, L., Adan, A., Natale, V., & Randler, C. (2013). Reviewing the psychometric properties of contemporary properties circadian typology measures. *Chronobiology International, 30(10), 1261-1271.*

Dipietro, J. A., Irizarry, R. A., Costigan, K. A., & Gurewitsch, E. D. (2004). The psychophysiology of the maternal–fetal relationship. *Psychophysiology*, *41*(4), 510-520.

Downes, M., Canty, M. J., & More, S. J. (2009). Demography of the pet dog and cat population on the island of Ireland and human factors influencing pet ownership. *Preventive Veterinary Medicine, 92*, 140-149.

Friedmann, E., & Thomas, S. A. (1995). Pet ownership, social support, and one-year survival after acute myocardial infarction in the cardiac arrhythmia suppression trial (CAST). *The American Journal of Cardiology, 76*(17), 1213-1217.

Gates, K.M., Gatzke-Kopp, L.M., Sandsten, M., & Blandon, A.Y. (2015). Estimating time-varying RSA to examine psychophysiological linkage of marital dyads. *Psychophysiology*, *52*(8), 1059-1065.

Grandner, M. A., Kripke, D. F., YOON, I. Y., & Youngstedt, S. D. (2006). Criterion validity of the Pittsburgh sleep quality index: Investigation in a non-clinical sample. *Sleep and Biological Rhythms*, *4*(2), 129-136.

Gunn, H. E., Buysse, D. J., Hasler, B. P., Begley, A., & Troxel, W. M. (2015). Sleep concordance in couples is associated with relationship characteristics. *Sleep*, *38*(6), 933-939.

Hasler, B. P., & Troxel, W. M. (2010). Couples' nighttime sleep efficiency and concordance: Evidence for bidirectional associations with daytime relationship functioning. *Psychosomatic Medicine*, *72*(8), 794.

Hoedlmoser, K., Kloesch, G., Wiater, A., & Schabus, M. (2010). Self-reported sleep patterns, sleep problems, and behavioral problems among school children aged 8 – 11 years. *Somnology: Sleep Research & Sleep Medicine*, *14*(1), 23-31.

Hoffman, C.L., Stutz, K., & Vasilopoulos, T. (2018). An examination of adult women's sleep quality and sleep routines in relation to pet ownership and bedsharing. *Anthrozoös, 31,* 711-725.

Holcomb, R., Williams, R.C., & Richards, P.S. (1985). The elements of attachment: Relationships maintenance and intimacy. *Journal of the Delta Society, 2*(1), 28-33.

Holt-Lunstad, J., Smith, T. B., & Layton, J. B. (2010). Social relationships and mortality risk: A meta-analytic review. *PLoS Medicine, 7*(7), e1000316. doi: 10.1371/journal.pmed.1000316

House, J. S., Landis, K. R., & Umberson, D. (1988). Social relationships and health. *Science, 241*(4865), 540-545.

Jarrin, D.C., McGrath, J.J., & Drake, C.L. (2013). Beyond sleep duration: Distinct sleep dimensions are associated with obesity in children and adolescents. *International Journal of Obesity, 37*(4), 552-558.

John, D., & Freedson, P. (2012). ActiGraph and Actical physical activity monitors: A peek under the hood. *Medicine and Science in Sports and Exercise*, *44*(1 Suppl 1), S86–S89. doi: 10.1249/MSS.0b013e3182399f5e

Johnson, T. P., Garrity, T. F., & Stallones, L. (1992). Psychometric evaluation of the Lexington attachment to pets scale (LAPS). *Anthrozoös*, *5*(3), 160-175.

Kafer, R., Lago, D., Wamboldt, P., & Harrington, F. (1992). The Pet Relationship Scale: Replication of psychometric properties in random samples and association with attitudes toward wild animals. *Anthrozoös*, *5*(2), 93-105.

Keklund, G., & Akerstedt, T. (1997). Objective components of individual differences in subjective sleep quality. *Journal of Sleep Research, 6*, 217-220.

Kertes, D. A., Liu, J., Hall, N. J., Hadad, N. A., Wynne, C. D. L., & Bhatt, S. S. (2017). Effect of pet dogs on children's perceived stress and cortisol stress response. *Social Development, 26*(2), 382-401. doi: 10.1111/sode.12203

Krahn, L.E., Tovar, M.D., & Miller, B. (2015). Are pets in the bedroom a problem? *Mayo Clinic Proceedings, 90*(12), 1663-1665.

Kushida, C. A., Chang, A., Gadkary, C., Guilleminault, C., Carillo, O., & Dement, W. C. (2001). Comparison of actigraphic, polysomnographic, and subjective assessment of sleep parameters. *Sleep Medicine, 2*, 389-396.

Kuzik, N., & Carson, V. (2018). Accelerometer Bluetooth proximity validation in parents and early years children. *Measurement in Physical Education and Exercise Science*, *22*(4), 287-293.

Lamprecht, M. L., Bradley, A. P., Tran, T., Boynton, A., & Terrill, P. I. (2014). Multisite accelerometry for sleep and wake classification in children. *Physiological Measurement*, *36*, 133–147. doi: 10.1088/0967-3334/36/1/133

Levine, G.N., Allen, K., Braun, L.T., Christian, H.E., Friedmann, Taubert, K.A., ..., & Lange, R.A. (2013). Pet ownership and cardiovascular risk: A scientific statement from the American Heart Association. *Circulation, 127*, 2353-2363.

Liu, X., Liu, L., & Wang, R. (2003). Bed sharing, sleep habits, and sleep problems among Chinese school-aged children. *Sleep*, *26*(7), 839-844.

Lozoff, B., Wolf, A. W., & Davis, N. S. (1984). Cosleeping in urban families with young children in the United States. *Pediatrics*, *74*(2), 171-182.

Maich, K. H., Lachowski, A. M., & Carney, C. E. (2018). Psychometric properties of the consensus sleep diary in those with Insomnia disorder. *Behavioral Sleep Medicine*, *16*(2), 117-134.

Marino, M., Li, Y., Rueschman, M. N., Winkelman, J. W., Ellenbogen, J. M., Solet, J. M., ... & Buxton, O. M. (2013). Measuring sleep: accuracy, sensitivity, and specificity of wrist actigraphy compared to polysomnography. *Sleep*, *36*(11), 1747-1755.

Markovich, A. N., Gendron, M. A., & Corkum, P. V. (2015). Validating the children's sleep habits questionnaire against polysomnography and actigraphy in school-aged children. *Frontiers in Psychiatry*, *5*, 188.

McConnell, A. R., Brown, C. M., Shoda, T. M., Stayton, L. E., & Martin, C. E. (2011). Friends with benefits: On the positive consequences of pet ownership. *Journal of Personality and Social Psychology, 101*(6), 1239 – 1252. doi: 10.1037/a0024506

McGrath, J.J., Noel, N.A., Burdayron, R. (2018) Development and validation of an actigraphy scoring protocol for sleep to define lights off/on. *Psychophysiology 55*(S1), S60.

McNicholas, J., & Collis, G. M. (2001). Children’s representations of pets in their social networks. *Child: Care, Health and Development, 27*(3), 279-294.

Meadows, R., Arber, S., Venn, S., Hislop, J., & Stanley, N. (2009). Exploring the I=interdependence of couples' rest-wake cycles: An actigraphic study. *Chronobiology International*, *26*(1), 80-92.

Meltzer, L.J., Walsh, C.M., Traylor, J., & Westin, A.M.L. (2012). Direct comparisons of two new actigraphs and polysomnography in children and adolescents. *Sleep, 35*, 159-166.

Michel, K. E., & Brown, D. C. (2014). Association of signalment parameters with activity of pet dogs. *Journal of Nutritional Science*, *3*.

Noland, H., Price, J.H., & Telljohann, S.K. (2009). Adolescents’ sleep behaviors and perceptions of sleep. *Journal of School Health, 79*(5), 224-230.

Owens, J.A., Spirito, A., & McGuinn, M. (2000). The children’s sleep habits questionnaire (CSHQ): Psychometric properties of a survey instrument for school-aged children. *Sleep, 23*, 1043-1052.

Pankhurst, F.P., & Home, J.A. (1994). The influence of bed partners on movement during sleep. *Sleep, 17*, 308-315.

Patel, S. I., Miller, B. W., Kosiorek, H. E., Parish, J. M., Lyng, P. J., & Krahn, L. E. (2017). The effect of dogs on human sleep in the home sleep environment. *Mayo Clinic Proceedings, 92*(9), 1368 – 1372. doi: 10.1016/j.mayocp.2017.06.014

Perrin, T. (2009). The business of urban animals survey: The facts and statistics on companion animals in Canada. *The Canadian Veterinary Journal, 50*(1), 48-52.

Sadeh, A. (2011). The role and validity of actigraphy in sleep medicine: an update. *Sleep Medicine Reviews*, *15*(4), 259-267.

Sadeh, A., Hauri, P.J., Kripke, D.F., & Lavie, P. (1995). The role of actigraphy in the evaluation of sleep disorders. *Sleep, 18*(4), 288-302.

Smith, B.P., Browne, M., Mack, J., & Kontou, T.G., (2018). An exploratory study of human-dog co-sleeping using actigraphy: Do dogs disrupt their owners' sleep? *Anthrozoös*, *31*(6), 727-740.

Troxel, W. M., Buysse, D. J., Hall, M., & Matthews, K. A. (2009). Marital happiness and sleep disturbances in a multi-ethnic sample of middle-aged women. *Behavioral Sleep Medicine*, *7*(1), 2-19.

Troxel, W. M., Robles, T. F., Hall, M. & Buysse, D. J. (2007). Marital quality and the marital bed: Examining covariation between relationship quality and sleep. *Sleep Medicine Reviews, 11*(5), 389-404. doi: 10.1016/j.smrv.2007.05.002

Tryon, W. W. (2004). Issues of validity in actigraphic sleep assessment. *Sleep*, *27*(1), 158-165.

Uchino, B.N., Cacioppo, J.T., & Kiecolt-Glaser, J.K. (1996). The relationship between social support and physiological processes: A review with emphasis on underlying mechanisms and implications for health. *Psychological Bulletin, 119*(3), 488-531.

van Eekelen, Varkevisser, M., & Kerkhof, G.A. (2003). Cardiac autonomic activity during human sleep: Analysis of sleep stages and sleep cycles. *Biological Rhythm Research, 34*(5), 493-502.

Westgarth, C., Heron, J., Ness, A. R., Bundred, P., Gaskell, R. M., Coyne, K. P., German, A. J., …, & Dawson, S. (2010). Family pet ownership during childhood: Findings from a UK birth cohort and implications for public health research. *International Journal of Environmental Research in Public Health, 7*(10), 3704-3729.

Wittmann, M., Dinich, J., Merrow, M., Roenneberg, T. (2006). Social jetlag: Misalignment of biological and social time. *Chronobiology International, 23*(1-2), 497-509.

Worthman, C. M., & Brown, R. A. (2007). Companionable sleep: Social regulation of sleep and cosleeping in Egyptian families. *Journal of Family Psychology*, *21*(1), 124.

Yang, C. K., & Hahn, H. M. (2002). Cosleeping in young Korean children. *Journal of Developmental & Behavioral Pediatrics*, *23*(3), 151-157.

Zanghi, B. M., Kerr, W., Gierer, J., de Rivera, C., Araujo, J. A., & Milgram, N. W. (2013). Characterizing behavioral sleep using actigraphy in adult dogs of various ages fed once or twice daily. *Journal of Veterinary Behavior: Clinical Applications and Research*, *8*(4), 195-203.

Zilcha-Mano, S., Mikulincer, M., & Shaver, P. R. (2011). An attachment perspective on human–pet relationships: Conceptualization and assessment of pet attachment orientations. *Journal of Research in Personality*, *45*(4), 345-357.

Table 1. *Demographic characteristics of pet co-sleeping groups.*

	Frequently (*n*=34)	Sometimes (*n*=31)	Never (*n*=123)	Total
	n (%)	*n* (%)	*n* (%)	*n* (%)
Sex (% male)	15 (44.1%)	15 (48.4%)	75 (61.0%)	105 (56.6%)
Sleep alone (% yes)	22 (64.7%)	22 (71.0%)	96 (78.0%)	143 (74.5%)
Sleep with someone else (% yes)	12 (35.3%)	10 (32.3%)	32 (26.0%)	54 (28.1%)
Allergies (% yes)	7 (20.6%)	9 (30.0%)	41 (34.7%)	78 (31.7%)
Asthma (% yes)	4 (14.3%)	4 (13.3%)	20 (16.9%)	41 (16.7%)
	M (SD)	*M (SD)*	*M (SD)*	*M (SD)*
Age	13.06 (1.74)	13.36 (1.82)	13.27 (1.73)	12.62 (2.03)
Parental Education (Years)	15.45 (2.89)	16.43 (3.03)	16.12 (2.91)	16.58 (3.18)
Household Income ($K CAN)	103.4K (61.9K)	98.2K (69.6K)	102K (59.6K)	99.2K (62K)

Table 2. *Comparisons of sleep dimensions between children who never, sometimes, and always co-sleep with pets.*

	Co-Sleeping Group			ANOVA	Hedges' *g* Effect Size			Glass's Effect Size		
	Frequently	Sometimes	Never	*p*-value	(95% CI)			$((M_1 – M_2)/SD_1)$, $(M_1 – M_2)/SD_2)$		
Duration					F vs. N	F vs. S	S vs. N	F vs. N	F vs. S	S vs. N
Self-report	530.56 (40.57)	528.12 (66.70)	519.40 (55.16)	.489	.213 (-.036, .462)	.044 (-.336, .424)	.151 (-.050, .352)	(.275, .202)	(.060, .037)	(.130, .158)
Parent-report	547.06 (56.76)	569.00 (57.08)	552.56 (55.88)	.259	.098 (-.284, .480)	.386 (-.110, .881)	.293 (-.695, .110)	(.097, .098)	(.386, .384)	(.288, .294)
Actigraphy	519.12 (42.87)	525.18 (56.31)	509.72 (43.87)	.198	.215 (-.274, .701)	.122 (-.608, .367)	.331 (-.729, .067)	(.219, .214)	(.141, .108)	(.274, .352)
Latency										
Self-report	14.17 (12.02)	16.94 (13.54)	15.08 (9.16)	.562	.095 (-.396, .586)	.216 (-.166, .598)	.143 (-.258, .544)	(.076, .099)	(.230, .205)	(.137, .203)
Parent-report	20.29 (12.92)	17.65 (8.06)	18.17 (7.97)	.424	.228 (-.265, .721	.242 (-.735, .251)	.065 (-.337, .467)	(.164, .266)	(.204, .328)	(.065, .065)
Actigraphy	16.88 (15.87)	13.54 (10.77)	16.09 (14.00)	.585	.055 (-.442, .333)	.245 (-.737, .247)	.190 (-.207, .588)	(.050, .056)	(.210, .310)	(.237, .182)
# Awakening										
Self-report	1.38 (1.26)	1.42 (1.15)	1.07 (1.05)	.148	.267 (-.662, .101)	.033 (-.454, .520)	.318 (-.720, .071)	(.246, .295)	(.032, .035)	(.304, .333)
Parent-Report	.61 (.68)	.58 (.59)	.65 (.74)	.895	.055 (-.370, .480)	.047 (-.591, .497)	.098 (-.340, .537)	(.059, .054)	(.044, .051)	(.119, .095)
Actigraphy	8.62 (4.92)	8.54 (5.86)	8.61 (6.42)	.998	.002 (-.390, .383)	.015 (-.505, .475)	.011 (-.387, .406)	(.002, .002)	(.016, .014)	(.012, .011)
WASO										
Self-Report	2.88 (3.62)	3.58 (4.45)	2.37 (2.98)	.210	.163 (-.555, .229)	.172 (-.330, .677)	.365 (-.041, .771)	(.141, .171)	(.193, .157)	(.272, .406)
Parent-Report	10.21 (9.63)	10.15 (10.08)	8.55 (9.64)	.564	.172 (-.557, .212)	.006 (-.497, .485)	.164 (-.568, .239)	(.172, .172)	(.006, .006)	(.159, .166)
Actigraphy	47.02 (32.97)	42.19 (26.01)	43.13 (26.67)	.738	.138 (-.525, .249)	.163 (-.657, .333)	.035 (-.366, .437)	(.118, .146)	(.146, .186)	(.036, .035)
Sleep Midpoint										
Self-Report	3:35 (1:17)	3:39 (0:55)	3:25 (0:59)	.621	.152 (-.540, .224)	.062 (-.428, .546)	.237 (-.158, .632)	(.130, .169)	(.052, .073)	(.255, .237)
Parent-Report	3:25 (0:58)	3:29 (0:50)	3:11 (0:52)	.162	.268 (-.645, .120)	.066 (-.418, .565)	.348 (-.054, .752)	(.241, .269)	(.069, .080)	(.360, .346)
Actigraphy	3:47 (1:17)	3:38 (0:53)	3:33 (1:06)	.542	.228 (-.260, .716)	.117 (-.662, .352)	.122 (-.473, .315)	(.182, .212)	(.117, .170)	(.094, .076)
MEQ	27.74 (4.77)	27.29 (5.08)	26.53 (5.41)	.441	.239 (-.249, .728)	.063 (-.578, .396)	.179 (-.536, .252)	(.254, .224)	(.094, .089)	(.150, .140)
Sleep Quality	7.56 (1.62)	6.81 (2.01)	7.23 (1.59)	.195	.206 (-.282, .694)	.411 (.028, .793)	.250 (-.145, .645)	(.142, .145)	(.463, .373)	(.209, .264)
Difficulty Sleeping	1.03 (1.03)	1.71 (1.37)	1.46 (1.27)	.079	.374 (-.030, .734)	.561 (.068, 1.061)	.190 (-.589, .201)	(.417, .339)	(.660, .496)	(.182, .197)

Table 3. Experiment A.1 –Signals detected in groups of OpenBeacon proximity sensors

Sensor Pairs			
Sensor ID	Total Recording Time (s)	# Signals Detected	Signals Detected/ Second
1A	Blank file; no data recorded.		
1B	43,200	32,250	.75/s
2A	43,201	33,191	.77/s
2B	43,200	32,458	.75/s
3A	Blank file; no data recorded.		
3B	43,200	32,458	.75/s
4A	43,200	31,804	.74/s
4B	43,201	32,740	.76/s
5A	Blank file; no data recorded.		
5B	Blank file; no data recorded.		
			Mean = .75/s
Groups of 5 Sensors			
Sensor ID	Total Recording Time (s)	# Signals Detected	Signals Detected/ Second
1A	43,200	80,163	1.86/s
2A	43,200	79,456	1.84/s
3A	43,201	80,655	1.87/s
4A	43,200	80,422	1.86/s
5A	43,200	79,899	1.85/s
			Mean = 1.86/s
Groups of 10 Sensors			
Sensor ID	Total Recording Time (s)	# Signals Detected	Signals Detected/ Second
1A	43,200	132,154	3.06/s
1B	43,200	131,559	3.05/s
2A	43,200	131,896	3.05/s
2B	43,200	131,917	3.05/s
3A	43,200	131,501	3.04/s
3B	43,200	132,128	3.06/s
4A	Blank file; no data recorded.		
4B	Blank file; no data recorded.		
5A	Blank file; no data recorded.		
5B	Blank file; no data recorded.		
			Mean = 3.05/s

Table 4. *Experiment A.2 – Sample data file showing detected signals, recording time, and recording group during prolonged data collection.*

ID [1]	Time (s)[2]	Restart Time[3]
1B	2	1
1B	2	1
3A	2	1
5A	3	1
3A	5	1
3A	5	1
3B	5	1
	...	
0x78C50000*	1523843072†	43
0x78C50000*	14	43
0x4AB50000*	15	43
3A	11911439†	43
	...	
0x5ACB0000*	1923689306†	49
0x00002472*	8304128†	49
3A	36	49
	...	
0xD4000094*	4143478106†	84
0xCA000094*	3464059498†	84
0x0000947B*	4168440532†	84
0x00169495*	9699328†	84
	...	
3A	2154821368†	91
1B	139	91
5A	63224	91
5A	10682502†	91
	...	
5A	2	102
3B	3	102
	...	
5A	155	102
	...	
5A	2	108

[1] ID shows the sensors that were detected by the sensor that collected these data.

[2] Time is defined as the number of seconds since the start of recording.

[3] Restart time indicates the number of times that the recording has restarted. i.e., group = 91 signifies that the timing restarted 91 times.

* Non-existent sensor was detected.

† Impossible time value.

Table 5. *Experiment A.3 - RSSI values and number of recordings per second in presence of potentially disruptive materials.*

Mean RSSI Values				
	Metal	Thin Fabric	Thick Fabric	Wood
1A	-44	-48	-48	-52
1B	-44	-49	-48	-53
2A	-45	-51	-47	-52
2B	-44	-49	-44	-53
3A	-45	-49	-53	-53
3B	-45	-48	-49	-52
4A	-45	-48	-47	-52
4B	-44	-49	-47	-52
5A	-47	-52	-48	-52
5B	-44	-51	-47	-52
Mean	-44.7	-49.3	-47.8	-52.3
Signals Detected per Second				
Sensor	Metal	Thin Fabric	Thick Fabric	Wood
1A	.76/s	.75/s	.77/s	.75/s
1B	.74/s	.73/s	.76/s	.75/s
2A	.78/s	.75/s	.74/s	.76/s
2B	.75/s	.74/s	.75/s	.74/s
3A	.76/s	.75/s	.75/s	.77/s
3B	.73/s	.76/s	.74/s	.76/s
4A	.75/s	.75/s	.76/s	.74/s
4B	.74/s	.77/s	.76/s	.75/s
5A	.74/s	.73/s	.75/s	.77/s
5B	.77/s	.78/s	.77/s	.76/s
Mean	.75/s	.75/s	.76/s	.76/s

Table 6. *Characteristics of dog owners and dogs.*

Humans	
Sex (% female)	100.00
Age (years)	30.29 (6.80)
Dogs	
Sex (% female)	28.57
Age (years)	6.08 (2.62)
Weight (lbs)	51.50 (30.32)
Duration of ownership (years)	5.15 (3.56)
Breed (%)	
Golden retriever	28.57
Labrador retriever	14.29
Toy poodle	14.29
Weimaraner	14.29
Mixed breed	28.57

Table 7. *Dogs' mean activity levels over a five-day period.*

Average Activity Counts	Sedentary Activity Counts	Light Activity Counts	Moderate Activity Counts	Vigorous Activity Counts	Sedentary Activity (%)	Light Activity (%)	Moderate Activity (%)	Vigorous Activity (%)
97.80	2.45	131.30	1042.30	4129.31	85.76	9.16	4.98	.10

Table 8. *Mean scores on pet attachment measures.*

	Mean (SD)
Lexington Attachment to Pets Scale (Range: 0-69)	50.83 (9.41)
Pet Attachment Questionnaire (Range: 26-182)	42.17 (9.81)
Anxiety (13-91)	16.33 (6.35)
Avoidance (13-91)	9.33 (1.63)
Pet Attachment Survey (Range: 27-108)	59.67 (3.78)
Relationship Maintenance (16-64)	32.50 (3.67)
Intimacy (11-44)	27.17 (1.72)
Pet Relationship Scale (Range: 0-84)	40.33 (5.05)
Affectionate Companionship (0-21)	14.33 (2.50)
Equal Family Member Status (0-21)	12.83 (3.31)
Mutual Physical Activity (0-21)	13.17 (2.48)
Inventory of Pet Attachment (Range: 0-245)	141.33 (31.25)

Note: Higher scores indicate greater attachment for all measures except the Pet Attachment Questionnaire; higher scores on the PAQ indicate greater attachment anxiety and insecurity.

Table 9. *Internal consistency and Pearson correlations between pet attachment measure total and subscale scores.*

	1	2	2a	2b	3	3a	3b	4	4a	4b	4c	5
1. Lexington Attachment to Pets Scale	**(.910)**	--	--	--	--	--	--	--	--	--	--	--
2. Pet Attachment Questionnaire	-.188	**(.805)**	--	--	--	--	--	--	--	--	--	--
2a. Anxiety	.095	.912*	--	--	--	--	--	--	--	--	--	--
2b. Avoidance	-.451	.920*	.721	--	--	--	--	--	--	--	--	--
3. Pet Attachment Survey	.195	-.187	-.278	-.108	**(.349)**	--	--	--	--	--	--	--
3a. Relationship Maintenance	.211	.158	-.009	.200	.893*	--	--	--	--	--	--	--
3b. Intimacy	-.023	-.748	-.592	-.664	.287	-.174	--	--	--	--	--	--
4. Pet Relationship Scale	.683	-.321	-.348	-.307	.290	.410	-.238	**(.445)**	--	--	--	--
4a. Affectionate Companionship	.164	.291	.118	.408	.056	.370	-.665	.718	--	--	--	--
4b. Equal Family Member Status	.833*	-.418	-.168	-.505	.075	.008	.146	.722	.502	--	--	--
4c. Mutual Physical Activity	-.041	-.387	-.601	-.362	.434	.449	-.008	.346	-.011	-.215	--	--
5. Inventory of Pet Attachment	.866*	-.126	-.051	-.226	.274	.338	-.120	.796	.553	.915	-.161	**(.948)**

Note: Diagonal values (in parentheses) show internal consistency.

Figure 1. *Experiment A.3 - Average RSSI values and horizontal distance.*

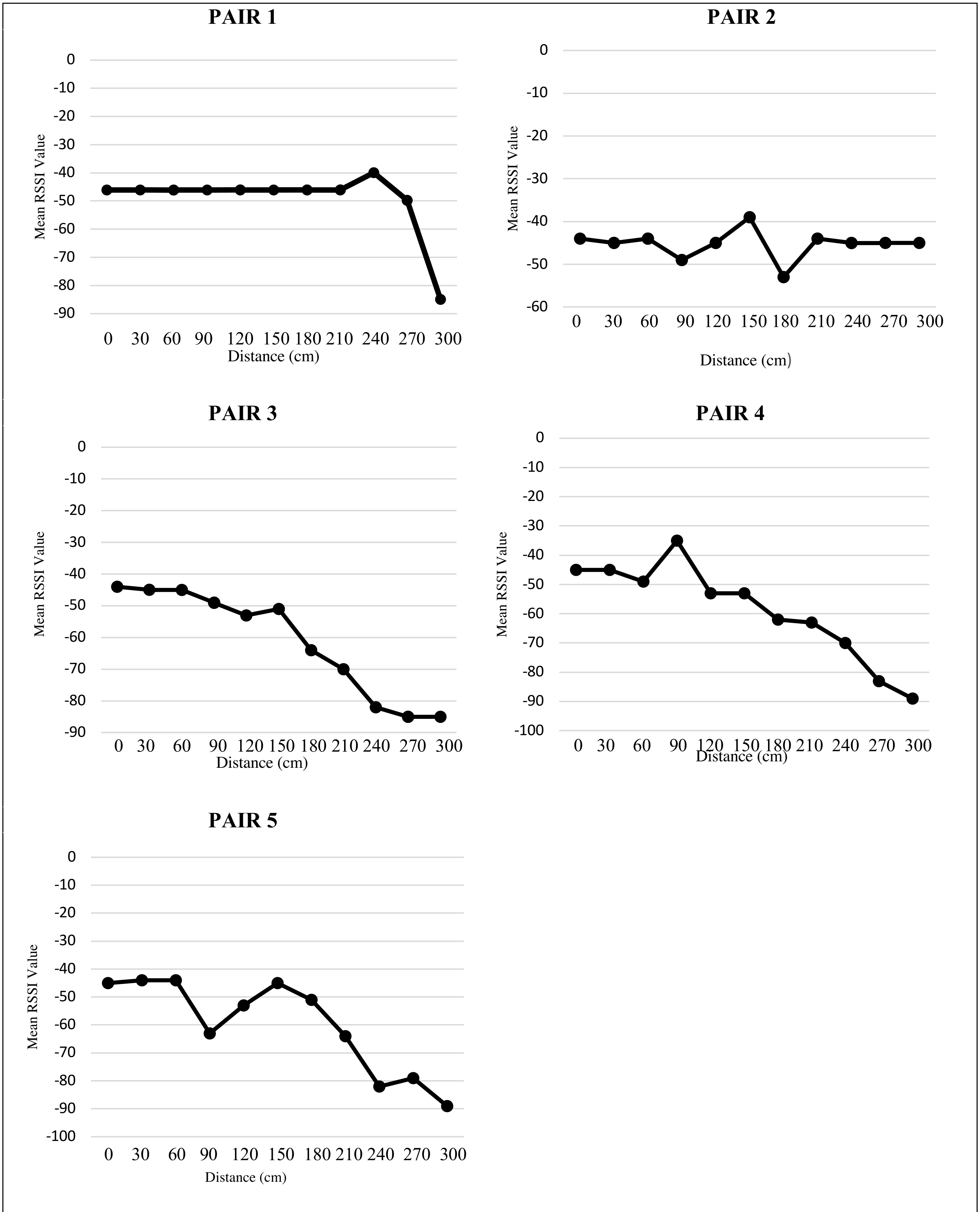


Figure 2. *Experiment A.3* - Figure 2. *Average RSSI values and vertical distance.*

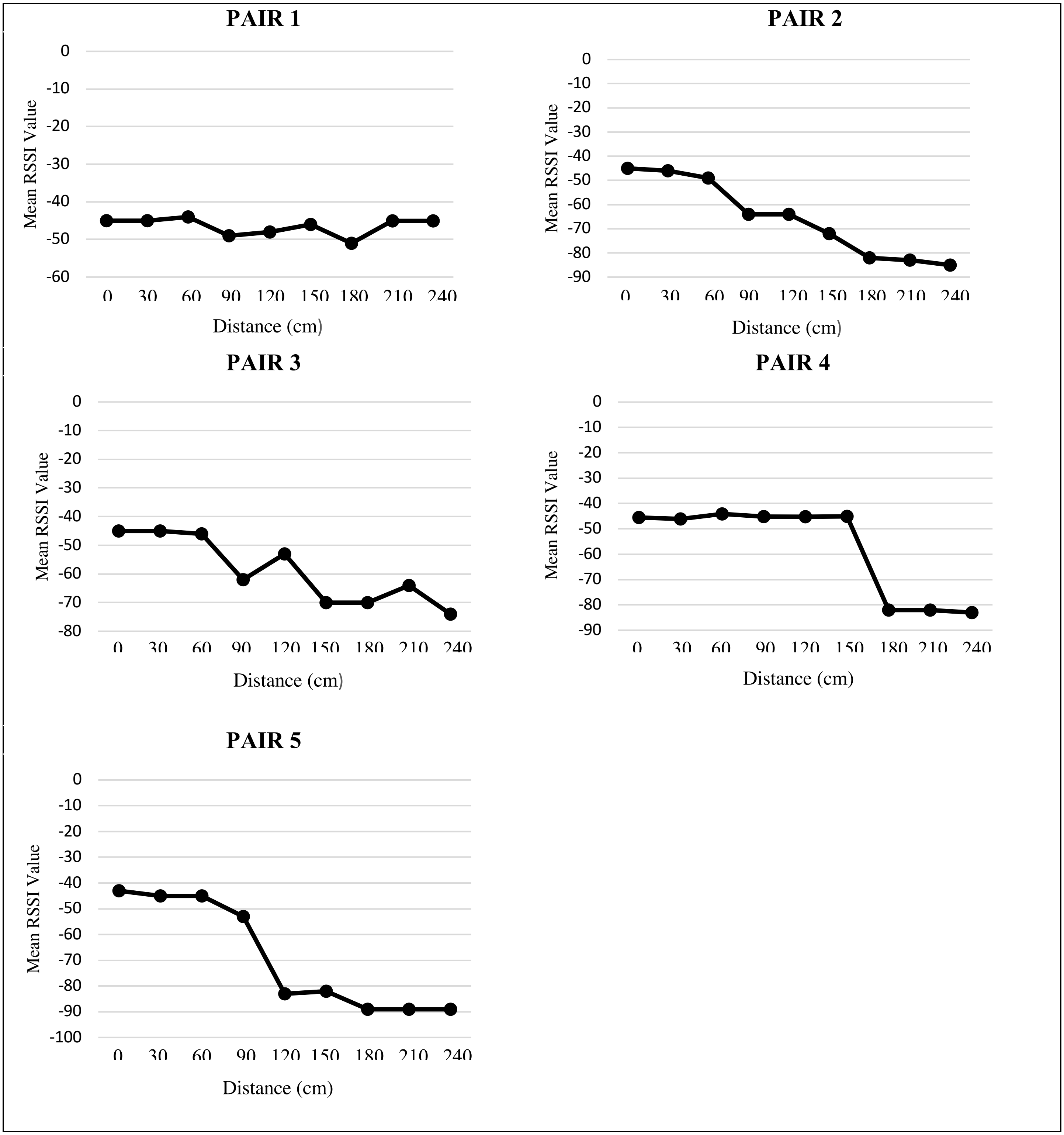
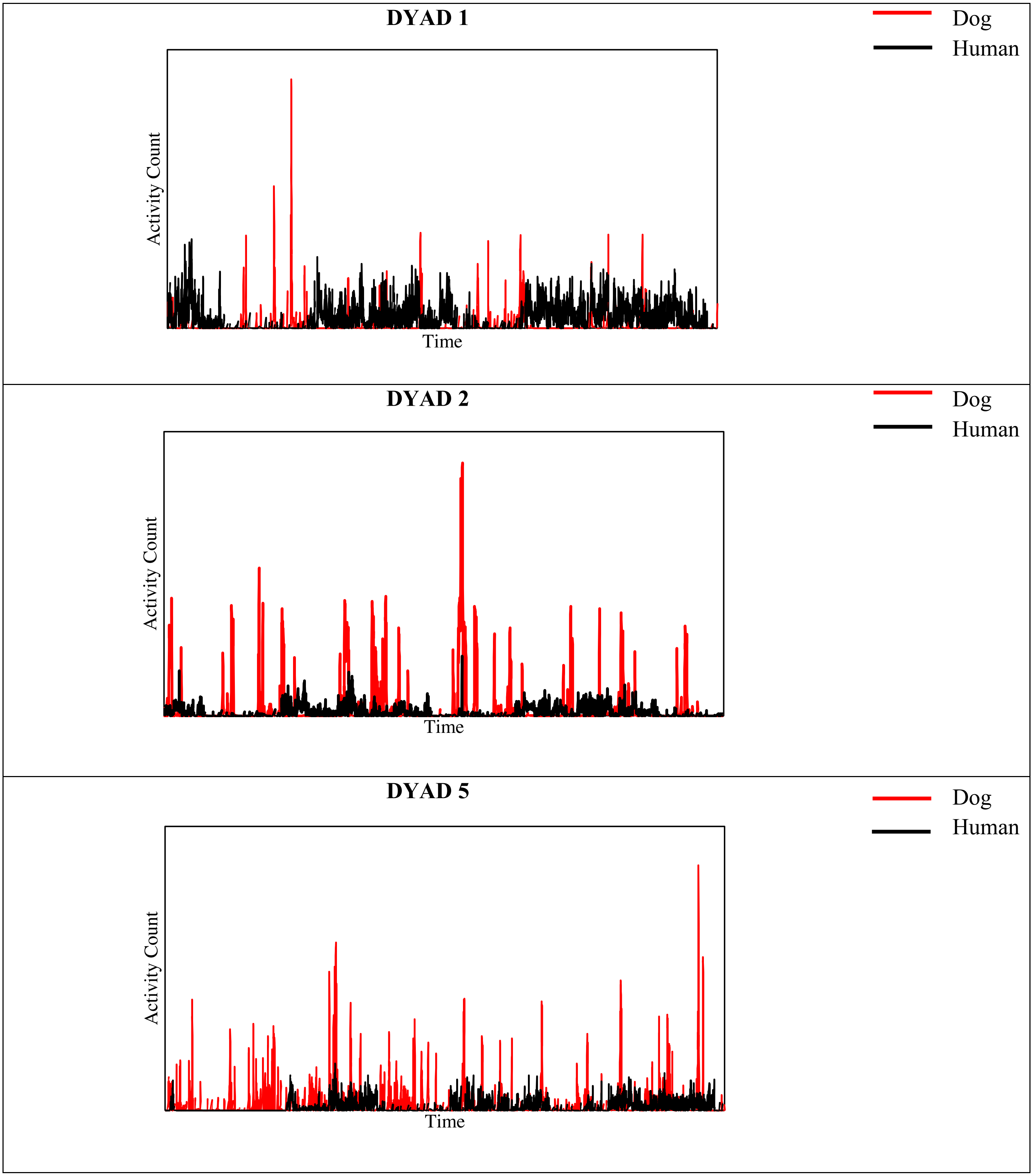


Figure 3. *Experiment B.1 - Five-day patterns in dog and human activity.*



Note: Dyads 3 and 4 are not presented. They did not provide complete data due to issues with battery life for the dog (Dyad 3) and human (Dyad 4) accelerometers.