Happy dogs and happy owners - using dog activity monitoring technology in everyday life

Happy Dogs and Happy Owners - Using Dog Activity Monitoring Technology in Everyday Life

Heli Väätäjä[1]**, Päivi Majaranta**[1]**, Poika Isokoski**[1]**, Yulia Gizatdinova**[1]**,
Miiamaaria V. Kujala**[2,3]**, Sanni Somppi**[2]**, Antti Vehkaoja**[4]**,
Outi Vainio**[2]**, Oskar Juhlin**[5]**, Mikko Ruohonen**[1]**, Veikko Surakka**[1]

[1] University of Tampere
Tampere, Finland
{firstname.surname}@uta.fi

[2] University of Helsinki
Helsinki, Filand
{firstname.surname}@helsinki.fi

[3] Aalto University
Helsinki, Finland

[4] Tampere University of Technology
Tampere, Finland
{firstname.surname}@uta.fi

[5] Stockholm University
Stockholm, Sweden
oskarj@dsv.su.se

ABSTRACT

Today, the markets are populated with dozens of devices for dog activity tracking and monitoring. Our aim was to get detailed insights on how dog owners use these devices in their everyday life. Two studies, an interview study with Finnish dog owners (N=7) and an international online questionnaire (N=35) were done to capture the motivations for using dog activity trackers, their utility, user experience, gained insights, and impacts of use. The results showed that the use of the devices was motivated by monitoring health, behavior, learning related issues, and by balancing the amount of activity and rest to an appropriate level. The tracker inspired the owners to spend more time with the dog and to be more observant to his/her behavior. In return, this had the potential to improve their relationship. The owners wanted to keep their dog happy, and in turn, perceiving the dog as happy made the owners happy. Based on the results, we also briefly discuss development needs for dog activity monitoring solutions.

Author Keywords

Dog; welfare; activity; tracker; wearable; monitoring; rest; training; learning; motivation; user experience; happiness.

ACM Classification Keywords

H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

INTRODUCTION

One of the key factors to recent growth in the pet wearable market is dog owners' increased interest and awareness towards dog wellbeing [10]. Pet owners are willing to spend more money on pets that provide companionship and attachment for them, as well as entertainment, fitness, and mental wellbeing [10]. Pet owners want to improve the connection with their pets, and the use of wearable technology can facilitate this purpose. Currently, the most important reasons for using this technology are tracking of location, and medical diagnosis and treatment [10]. Behavior monitoring and control has been less in the focus.

In this paper, an **activity** refers to a thing that a dog or the dog and its owner do or have done as a team [27]. An **action**, in turn, refers to a goal driven and strategic act to achieve an aim [27], which is not in the focus of this paper when referring to a dog's activity. Instead, it can relate to the human perspective when monitoring dog's activities and using this information and gained insights in everyday life.

Activity tracking or monitoring solution consists of a wearable device and accompanying software (typically a mobile phone app) which monitors and tracks physical activities. Usually activity tracking is based on the measurement of three dimensional acceleration, which can be categorized to different activity levels by using signal processing algorithms. In addition to activity tracking, the device may also include other features such as distance (if GPS is available or steps are calculated), calorie consumption, or even heartbeat, which is available in many human trackers but still rare in devices meant for animals.

There are a few studies on users' expectations of dog monitoring technology [29, 28, 18]. However, studies focusing specifically on the pet owner's real-life experiences of the activity monitoring and smart collars are rare [1, 2, 26]. Studies are needed to understand how the devices, data, and visualizations are actually used for the benefit of both the dogs and the owners, and to identify development needs and opportunities for the future. Such studies can pave the way to identify future technological and business potential in human-animal interaction.

PRIOR RESEARCH

Activity monitoring technology

We confine ourselves here reviewing prior literature in which the pet owners view and interpret the data measured from the dog. Canine-centered computing (for an overview, see [9]), where a dog is the user interacting with the technology, is out of the scope of this paper.

Expectations and Concerns

When studying the expectations and wishes of dog owners for dog monitoring technology, Paldanius et al. [29] and Paasovaara et al. [28] identified many common expectations. Pet owners were interested in monitoring activity and wellbeing, as well as monitor and interact with the dog that was left alone at home, or temporarily in a car or a hotel. Outdoor positioning was useful while searching for a lost dog, or hunter's companion dog. Technology was expected to be useful in many situations, for example, while sick, recovering from operation, or raising pups. Various condition indicators such as body temperature, panting, changes in eating and drinking, or even heart beat monitoring were on the wish list to get more accurate information on the dog's wellbeing. People wanted to get remote information in real-time (e.g., find out if and why a dog misbehaves) and long-term statistics to see changes in dog's wellbeing.

Common reported concerns included reliability, durability, battery life, collar compatibility, and cost of the technology [28, 29]. The pet owners, some of whom had used webcam or similar technology for checking how their dog was doing at home, also expressed a fear that using the system may require too much time and effort, especially in real-time situations. The technology may also raise (perhaps unnecessary) concerns and related stress for the dog owners (e.g. when seeing the dog is bored). Notifications of the dog status rather than constant monitoring of device outputs was preferred. It was also important that the technology should work as a means to get information about the dog's condition instead coming between the dog and its owner [29].

Lawson et al. [18] included not only pet owners but also animal behavior experts in their study of expectations towards dog technology. Pet owners were excited about the possibility of using technology for dogs to improve animal welfare, as a teaching tool, to collect evidence, share data, aid decision making, or create peace of mind. Concerns included worries about measurement accuracy, cost, over-

complication of things, potential extra anxiety (for humans), over-diagnosing, replacing direct observation with technology in learning about the dog, conflicting and changing the nature of human-animal relationship, and even support for abusive behavior (if misused). They noted that owners have a strong interest in understanding their pets' emotions, but are not concerned about how it is enabled. Animal behavior experts, on the contrary, expressed concerns about validation procedures and how computer could understand the dog behavior since even they don't understand them properly yet. Individual differences may also be a challenge. Lawson et al. [19] questioned if the technology is for the pet's benefit or for the amusement of the owner.

In order to support human interpretation of dog monitoring technology, it must provide reliable data. Activity tracking algorithms developed for humans cannot be directly used with animals. Even simple activity classification with only three categories (minimal activity, walk, and run) gives poor results if it does not take into account the dog's breed and size [38]. On the other hand, with a proper training of the algorithms and personalization for different types/sizes of dogs, it is possible to differentiate a number of activities based on different movement patterns. In their pilot study, Ladha et al. [16] were able to classify 17 different activities and poses with about 70% accuracy. These included barking, chewing, digging, drinking, eating, excreting, jumping, laying, pawing, running, shaking, shivering, sniffing, sitting, urinating, walking, and unspecified activity. Using videos and depth-sensing trackers, computer vision researchers attempt to track animals' body postures and orientation (e.g., [30]). Similar to activity tracking, monitoring rest also benefits from an algorithm that is tuned for dogs [17].

There is a number of activity trackers already on the market that are able to track and discriminate at least a few main activity levels from none/low level to medium and high levels (terms for these levels vary in different implementations). Validation studies are scarce, but the few that are available indicate that at least some of the trackers are accurate enough for tracking dog activity levels reliably. For example, Yashari et al. [40] compared Whistle with (validated) Actical and found them to be statistically equally accurate. Valldeoriola Cardó et al. [36] recorded and annotated videos of 70 dogs performing pre-defined static (lying, sitting, and standing) and dynamic (walking, treat search, trotting, and playing) behaviors to get the ground truth of the activities. The dogs wore three trackers (ActiGraph GT9X Link, Kaunila, and FitBark), which were found to be reliable in distinguishing certain static and dynamic behaviors (main categories were clear but similar behaviors may not be separable, e.g., walking and treat search). They concluded that their results validate the functionality of these devices.

It should be noted that the location and attachment mechanism of the trackers may somewhat affect the results

[31]. More importantly, as the monitoring device is worn by the dog there are certain safety, comfort, and durability issues to be considered. Valentin et al. [35] discussed safety and comfort of the devices attached either to a collar or a harness, taking into account the pressure to the neck, weight, and size of the device related to the dog's size.

One of the often mentioned wishes by dog owners is to know whether the dog is happy or not. There are startups and crowd-funding campaigns entering into the area that claim to do much more than just simple activity tracking, for example, read pets' emotions (based on our quick informal online survey of the current dog technology). It remains to be seen if and how well these claims will be fulfilled; this is an area for future research and scientific validations.

Applications of Dog Activity Measurement Devices

The obvious way to use an activity tracker for both humans and animals is for supporting exercise, which in return may support weight control and physical wellbeing. Activity tracking technology may increase awareness and motivation and promote healthier lifestyle [26].

As humans do walk dogs, one can make rough estimation of the dog's activity by measuring the owner's activity. Pedometers, which measure the activity in number of steps, have been used to study how people and dogs exercise together [5]. For example, Warren et al. [37] showed that higher daily activity of the owner correlated with healthier body condition of the dogs.

An activity monitoring device may also be useful in monitoring the recovery from an illness, e.g., by showing increased activity levels in dogs that received treatment for osteoarthritis [3]. Another option to track physical activity is to exploit global positioning system (GPS) that can measure the distance and speed. For instance, Bruno et al. [4] applied positioning system in evaluation of the efficiency of osteoarthritis treatment.

Activity monitoring technology may also help in adoption of shelter dogs [2]. When new shelter dog owners were given the Whistle monitoring device with a smartphone application, the device helped them to meet the dog's needs and increased bonding between the animal and the owner. Assessing and predicting the suitability of a dog for a working dog occupation requires expert monitoring and assessment. Alcaidinho [1] suggested that dog activity monitoring technology might help here. For example, based on a pilot study, it seems that good rest during the night corresponds with good training outcomes.

A review of the current smart computing and sensing technologies for domestic, farm, and wild animal welfare can be found in Jukan et al. [14], including a classification of application fields and technologies used for each of these.

Dog welfare and technology

We next describe some basic concepts related to animal welfare to ground our work and contribution of this paper.

Welfare includes both a physical and psychological component, covering both fitness and a sense of mental wellbeing of the animal [24, 25]. It is noteworthy, that it covers both biological functioning and affective states, such as emotions, pain, suffering, and frustration [24].

The Five Freedoms outline originally the ideal states of animal welfare (Table 1). They are generalizable to pets as well [23]. The Five Freedoms framework is taken as the minimal requirement for animal welfare. While it is not seen as a characterization of "a good life", it still provides a simple and generally accepted basis for discussing animal welfare.

Freedom	Explanation
Freedom from Hunger and Thirst	Ready access to fresh water and a diet to maintain full health and vigour.
Freedom from Discomfort	An appropriate environment including shelter and a comfortable resting area.
Freedom from Pain, Injury or Disease	Prevention or rapid diagnosis and treatment.
Freedom to Express Normal Behaviour	Sufficient space, proper facilities and company of the animal's own kind.
Freedom from Fear and Distress	Conditions and treatment, which avoid mental suffering.

Table 1. The Five Freedoms [8].

As more knowledge is accumulating from animal research, especially on animal welfare, cognition, and emotions, the Five Freedoms framework has been extended to cover more comprehensive viewpoints of animal welfare. The goal of an elaborated Five Domains model (nutrition, environment, health, behavior and mental) is to minimize the negative experiences, and enable and support positive experiences, covering animal's mental state and affective experiences [22]. Aim is to support animal's engagement into rewarding activities, such as social interactions with humans and conspecifics, enriched eating possibilities, and other rewarding behaviors, such as exploration of environment [ibid.]. When considering dogs, the most typical reasons for lowered welfare include, for example, being alone for long periods of time, separation anxiety (state of fear), lack of environmental stimuli or inability to express natural behaviors [11, 12, 20, 32, 33]. When turning to technology, anxiety and fear caused by the use of technologies or tools that create aversive stimuli (e.g., ultrasonic, citronella & electric collars) can be reasons for lowered welfare as well.

Summary of literature

In summary, technology can help to interpret dog's state and activity patterns for various purposes. Activity tracking

technology can support improving dogs' chances for better quality life [22] as humans using the technology will have more insight about their dogs. This in turn can lead to better dog-human interaction. One way to get insights into potential direct and indirect effects of new technologies on dog welfare is to collect dog owners' views. This can provide a framework for discussion of future development needs in this area.

STUDY 1: QUALITATIVE INTERVIEW

The goal of Study 1 was to identify the motivations to start using dog activity monitoring solutions, goals of use in everyday life, practices of use, the types of understanding gained and possible impacts of use. Study 1 took place in May-June 2017 in Finland.

Method: A semi-structured interview was used to explore the above questions.

Participants were recruited by a call for participation in chosen Facebook groups, and by publishing the call on the website of our research project. Table 2 presents the information on the seven interviewees' dogs (one male and six female owners). Interviews with a length varying from 30 to 50 minutes were done over the phone (4/7) and face-to-face (3/7) in May-June 2017. Hand-written notes were made during the phone interviews. Face-to-face interviews were audio recorded.

Trackers: Information on the dogs wearing activity monitors, devices used, and the duration of usage are presented in Table 2. Two participants used trackers on two dogs, and one used the same tracker on two dogs.

Transcribed interviews were analyzed by qualitative content analysis. Main emerging themes were identified and grouped. As the coding advanced, we created top level categories. We used the findings in preparing the online survey for the next phase of the research in Study 2.

ID	Age	Gender	Breed	Device/solution	Length of usage in months	No. of dogs in household
P01	2y 5m	Female	Bordercollie (BC) mix	Kaunila Activity Monitor	4	1
P02	3y	Male	Parson Russell terrier	Whistle Activity Monitor	25	1
P03	1y 10m	Female	German short-haired pointer	Garmin GPS tracker for hunting dogs when dogs at large, Sportstracker on mobile phone when working as sled dog	8	2
P04	1y 7m	Male	Spanish Waterdog	Whistle Activity Monitor	1	1
P05	8y 6m	Male	Kooikerhondje	Whistle Activity Monitor	20	1
P06	10m	Female	Bordercollie	Kaunila Activity Monitor	5	2
P07	7y	Male	Danish-Swedish Farmdog	Tractive Motion	18	2

Table 2. Information on the interviewees' dogs.

Results of Study 1

Initial motivations for use

Three themes emerged: *supporting training* activities in physically active and challenging hobbies like agility and sled dog racing (2/7), *monitoring behavioral issues* (3/7), and *following up daily activity* in general (3/7). As the use progressed and the owners learned about their dog's behavior or there was a substantial change in the life of a dog, such as a surgery, the motivations and goals of use changed.

Motivations in continuous use

After taking the activity tracking into use and gaining experience on utilizing it in everyday life, the motivations to use the solutions included more specific and diverse motivations. These motivations were categorized as follows.

First, most often mentioned motivations were related to *improving dog welfare*, including physical and mental wellbeing. Interviewees discussed monitoring and balancing the activity and rest based on the specific dog's needs:

> *"I follow up the amount of activity and exercise when they are free, and estimate the amount of exercise that is still needed."* (P07, Danish-Swedish Farmdog, male)

Following changes in behavior and activity were also described:

> *"It is useful that one can understand the relation of behavior to activity and alertness. Changes tell about welfare or health problems."* (P02, Parson Russell, male)

Weight control and activity based feeding adjustments, as well as rehabilitation support after a surgery or injury were mentioned as concrete use cases for the solutions.

Second, *supporting learning* was explained to be an important goal as dog's ability to concentrate and learn was influenced by the right balance of exercise, other activity, and rest. This was discussed by two interviewees who had dogs that they described as restless or hyperactive. One interviewee explained this as follows:

> *"The device helped to understand the entity, and since rest is important for cognitive abilities, the device helped to concretize that learning is difficult, if there is not enough rest. [...] The advances in learning can be seen in the measures like rest, and the changes in the amount of rest. One can also see things like the kids could leave the dog alone, and not activate him with a ball."* (P02, Parson Russell, male)

Third, two interviewees discussed supporting *physical training of sporting dogs* for competitions in case of sled dogs and agility. Monitoring supported systematic training by following up and taking care of daily physical activity and rest in general, as well as ensuring recovery within and after the training session. Training related activities, such as travelled distance, speed (mean and maximum), and intensity of the physical activity were mentioned to be among those being monitored.

Finally, *remote monitoring* was mentioned as one long-term usage motivation while away at work or travelling:

"If the dog is in someone else's care, one can see what has happened. How often he has been out to take a walk and has he been active. I know how things have been going for the dog. […]. When you have been away, it is somehow more concrete compared to when someone is telling you the same thing." (P05, Kooikerhondje, male)

Pre-planning of daily activities when arriving home based on the remote monitoring was also discussed. The activity data provides concrete information on what has been going on during the day as described by one interviewee:

"I can take a look at work, for example, that now he has taken a walk. I can draw a conclusion beforehand [before arriving home] if he has been out walking, and whether we need to go out immediately or can I eat first. At the moment, this is what it is handiest for." (P05, Kooikerhondje, male)

Insights and impacts - The discussed insights focused on better understanding of the dog's behavior as well as things, which affect the dog's welfare more broadly. These in turn were described to change, e.g., the owner's behavior to consider not only activity but also the need for rest.

"I monitor the activity levels every day and the impact of activity on her behavior. At the same time it has impact on me – at first I tried to get her running to get a lot of the highest activity level, but now I am much more thinking about rest and calming down." (P01, BC mix, female)

Use of activity information - As exemplified in some of the previous quotes, interviewees used the provided information by the activity tracker to ***support their decision making and interpretation of the dog's behavior and wellbeing as well as finding cause-effect patterns***. All monitoring was discussed in terms of first looking at dog's behavior and appearance, and how the dog appeared to be feeling. Secondarily, measurements were compared to perceptions and observations in real-life and then the interviewees reflected upon them to take action and make decisions.

To understand what causes a certain type of behavior or activity, the users tend to start to look for the answer in the activity data measurements and visualizations.

"I tried to make sense of what was the day like after she was very restless during the night. If she was still restless after she had gotten something really good to chew on, or if she had been activated otherwise with mentally stimulating activities." (P06, Bordercollie, female)

All interviews identified the happiness and overall welfare of the dog as the ultimate goal for them. The used solutions, whatever the purpose of their use was, were supporting and ensuring this goal. The sled dog hobbyist described:

"I can see that the dog is not affected by the trained distance, the impacts are concretized and the link to training becomes visible. One can see that the dog is enjoying the training and is happy and well, even though the training distance has been long. His primary role is in any case to live in the household with kids." (P03, German Short-haired Pointer, female)

Development needs - Interviewees wished for more comprehensive statistics than currently available, such as different types of summaries and comparisons. They also wanted support to recognize and understand cause-effect patterns. Currently, the systems do not support these inferences. Interviewees also expressed that activity information alone is not enough. Context-related information would be important, including information related to context dimensions, i.e., physical, social, temporal, task, and technology and information used and available [39].

Context information helps the user to remember what happened on what day, where, when, with whom, as well as the nature of activity or exercise going on, possible goals, etc. In addition, changes or interventions, or other instances in daily life or training would be important to note to track changes and impacts. This type of information helps to memorize, compare, and interpret the data any time later on. In some hobbies, it is not possible to wear any equipment or accessories during the activity due to safety reasons, for example. This calls for solutions to manually add information to activity data. Manual or automated categorizing was also wished for different types of activities and training. The manual categorizations could be used to teach machine learning systems for personalized activity recognition. One interviewee also mentioned that the data provided by the current solution she used was boring, as only the activity intensity and daily minutes of activity and rest was provided, while the life with the dog is much richer and complex. She mentioned, for example, comparisons between herself and the dog, as well as the proximity between them to be interesting. Open access to own dog's data and saving of the data in the service over the years for following and comparisons over time were also called for.

STUDY 2: ONLINE INTERNATIONAL SURVEY

The aim of Study 2 was to confirm, corroborate, and extend the results from the first study by an international online survey with both open and closed questions. Study 2 took place during summer-autumn 2017.

Method: For Study 2, we created a questionnaire with themes identified in Study 1. These were expanded with specific theme areas with closed-ended questions. In addition, we included themes identified in previous research, especially related to the needs and expectations on dog monitoring technology. We also reviewed the background questions in validated dog behavior related questionnaires, for example, C-BARQ questionnaire [13], to ensure that the background questions related to the dogs and family covered sufficient information.

The questionnaire included 5-point Likert statements under themes related to motivation of using a tracker (10 questions), its utility (12), user experience (8), and added value (6). Respondents were asked to rate how well the statements reflected their experiences and thinking (from 1 = strongly disagree to 5 = strongly agree). After each statement, there was an open text field for clarifications and additional information. There were also specific open questions about participants' experiences and insights. We asked the participants to describe what were their most positive and negative experiences with the tracker. For insights, we asked what they have learned or understood more deeply about the dog when using the device, and, if and how the device has affected their relationship with the dog.

In the following, the results are expressed as mean values ± standard deviation. The Likert statements were further analyzed with non-parametric correlation analysis using Kendall's tau coefficient 2-tailed significance test. Open questions were analyzed by qualitative content analysis by two researchers, who identified themes in the participant's answers and also calculated how many times each theme was discussed. Repeating, interesting, or surprising themes get more emphasis in our reporting that follows.

Participants were recruited through Facebook groups dedicated to dogs. Ten small dog related prizes were raffled between those participants who responded before the deadline and had left their contact information (voluntary).

Results reported in this paper are based on responses from 35 participants (1 male, average age 37, range 20-54 years) from 10 different countries (Canada, UK, USA, Norway, Finland, Austria, Slovakia, South Africa, Sweden, Switzerland; note that not all respondents revealed their location). Many of the respondents were active users of human heart rate monitors or activity trackers, 24 of them used one of these daily (2 weekly, 2 rarely, 7 not using a tracker). Most of them (two thirds) were positive towards new technology: 12 (early adopters) used the technology among the first; 12 (early majority) started using the technology after others have tried it; 11 (late majority) used it after a consideration; and 0 (laggards) avoided the technology [15, 34]. Therefore, the sample was biased, possibly reflecting the novelty of the devices and not yet being adopted by the masses.

Half of the respondents had more than one dog (17 having at least 2 dogs, max 10). If the respondents were using the tracker on several dogs, we asked them to report regarding the dog that they enjoyed the use of the tracker the most or to whom it was most useful. For 11 respondents, this was their first dog, 24 reporting having had other dogs before.

The dogs (20 female, 15 male) represent different ages (range 1-16 years) and breeds (7 mixed, various pure breeds of different sizes). Most dogs (26) did not have known health issues (6 minor, 2 moderate, and 1 serious health issues, including problems with, e.g., allergies, epilepsy, heart, kidneys, joints and mobility) nor behavioral issues (21 none,

11 minor, 3 moderate, including, e.g., separation anxiety, fear or aggression towards strangers). All dogs lived indoors, most in suburban (21) or urban (12) environments, and two in countryside. Most dogs (31) were considered to be pets/companions, 16 were active in sports such as agility, 5 in breeding/showing, 5 working (e.g., therapy dogs and mobility assistants were mentioned in the additional information), and one field trial/hunting dog. Typical amount of daily physical activity was about two hours, varying from 15 min to 12.5 h. Also, the average time spent alone at home during work days varied a lot: 10 none, 3 below 3 h, 9 up to 5 h, 4 up to 8 h, and 6 dogs spending over 8 h alone at home.

Trackers used by the respondents included 27 Fitbark, 4 Petkit, 2 Whistle, 1 Poof activity tracker, and one Kardia AliveCor heart rate tracker (device intended for human use was used with the dog). Some mentioned also having experience in using other dog activity trackers (e.g., Bean, Kaunila, Whistle) in addition to the one they reported on for the study. Most (31) used the tracker all the time including nights, others used it during daytime especially during training, walking or when the owner is away (the options were not exclusive, i.e., one could report using it during the day and also during walks). One dog owner only used the tracker during walk and one after activity (for monitoring the dog's heart condition). More than a half (16) of those who used Fitbark had linked it with their own activity tracker (typically Fitbit but also some other devices were mentioned); some found it fun and interesting to compare their activity points but others did not pay attention to it or did not find it useful. The respondents were also active in checking the data from the device, either several times a day (17), daily (10), several times during the week (5) or at least weekly (2); these include, e.g., checking after training, when returning home, or later at the day to see the progress of the daily goal. On average, the respondents had used a dog activity tracker for 11 months (median 8, range 1-50 months).

Results of Study 2

Motivation for using the trackers
Obviously, people who buy dog activity trackers want to track the dog's daily *activity levels* (32 respondents strongly agreed, 4.89 ± 0.40) or to ensure their dog gets enough *exercise* (28 strongly agree, 4.57 ± 0.98). In addition, the majority wanted also to track the dog's daily amount of *rest* (4.31 ± 1.02). The motivation of tracking the rest in addition to the activity level was emphasized in the free comments, e.g., *"I want to better understand the pattern and balance between rest and activity"*.

People are motivated to *monitor remotely* the dog's wellbeing *when the owner is away* (4.03 ± 1.36) or monitor the activity when *somebody else takes care of the dog* (4.06 ± 1.21).

Other motivations included monitoring *performance and recovery* from exercise (3.77 ± 1.14), monitoring *health*

and/or recovery from illness (3.71 ± 1.27) as well as monitoring due to *behavioral issues* (3.06 ± 1.53). There was no statistically significant correlation between those willing to monitor health or behavioral problems with those who reported having related problems with their dogs. This indicates that the wish to monitor health and behavioral issues is a more general need for many dog owners. Motivation to understand the dog's *feelings* got varying ratings (3.42 ± 1.38, median 3 = neutral, range 1-5). This is understandable as the devices do not directly answer to this; it requires the owner's indirect interpretation of the relationship between behavior and activity (e.g. the dog requiring a certain amount of activity and rest in order to be "happy", according to the owner's interpretation).

Finally, many simply wanted to try out new technology on their dogs (24 strongly agree, 4.43 ± 1.07). The respondents' reported attitudes towards technology reflect this finding.

Respondents could also freely describe their motivations. Calorie consumption was mentioned by three participants, for fitness tracking in conjunction with weight monitoring or during different activities. One wanted to track the dog on trips. Specific health related motivations included finding out how much activity the dog can have before triggering arrhythmia, check for excess movement indicating a seizure, see if the dog is in pain from ear infections or allergies, or monitoring recovery from illness. Tracker use being fun was mentioned also as a motivation.

Utility and usefulness

In addition to motivations, we wanted to find out the actual utility and usefulness of the solution (i.e., tracker and accompanying software) in the dog owner's everyday life. An overview of the responses is shown in Figure 1.

Not surprisingly and statistically correlating with the motivation to track the dog's activity levels (r = .45, p < .01), most respondents strongly agreed on the perceived usefulness of getting an *overview of the dog's activity levels* (29 strongly agreed, 4.74 ± 0.66). Most also felt the solution to provide *relevant* information of the dog (4.5 ± 0.74) and that the information is *reliable* (4.09 ± 1.15). In the free-form comments, it was noted that the activity and rest is well presented but the calculation of daily energy expenditure (calories burned) is not reliable.

Majority agreed that the solution enables them to *achieve their goals* (4.57 ± 0.61). They felt the solution gives them a better opportunity to *understand the dog's life* (4.20 ± 0.99)

and enable them to *learn new things* about the dog (4.03 ± 1.01). Being able to understand the dog's life and learn new things about it were both correlated with the motivation to monitor the dog when the owner is away (r = .35, p < .05 and r = .44, p < .01, respectively). The freely written comments on insights about the dog affirm the need and usefulness of the trackers: they help in understanding the dog's life when the owner is away or otherwise does not immediately see it (e.g., during the night).

Respondents also felt the solution helps them to *monitor or notice changes* in the dog's behavior or wellbeing (4.23 ± 0.91); being able to notice the changes was important to many respondents. Many emphasized changes as their interest also in free-form comments.

There was more disagreement on the rest of the statements. These were related to the usefulness of the solution in helping to *balance feeding and daily activities* (3.89 ± 1.08), to *remember and plan training sessions* (3.34 ± 1.35), enabling discussion and *planning training* with peer trainers or a coach (3.06 ± 1.28) as well as enabling discussion about health issues and *planning treatments with the veterinarian* (3.54 ± 1.36). These statements may not have been relevant to all dog owners, which may explain the greater variation in the responses. The perceived usefulness of enabling discussion and planning treatments with the vet correlated with the motivation to monitor health (r = .41, p < .01). The motivation to use the solution for weight loss or to track calories burned was not included in the statements. However, three respondents mentioned using the solution for weight loss; they all strongly agreed that the solution helps to balance the amount of feeding and daily activities.

When asked if the solution provides sufficient features that meet the dog owner's needs most somewhat or strongly agreed (3.83 ± 1.07). Those who disagreed, mentioned, for example, that they would need a GPS for finding the dog if it runs off. They also complained that the tracker gives false or insufficient information (e.g., false calculation of calories, or indicates over exercise after a short walk, or having hard time understanding if their own dog is having enough, too much or too little exercise). When reading these responses, one should remember that there are differences in the features offered by the trackers that may have affected the ratings for usefulness, and that our sample does not accurately represent the solutions that are in the market (some missing altogether and some overrepresented). However, it gives an idea of the utility of the trackers.
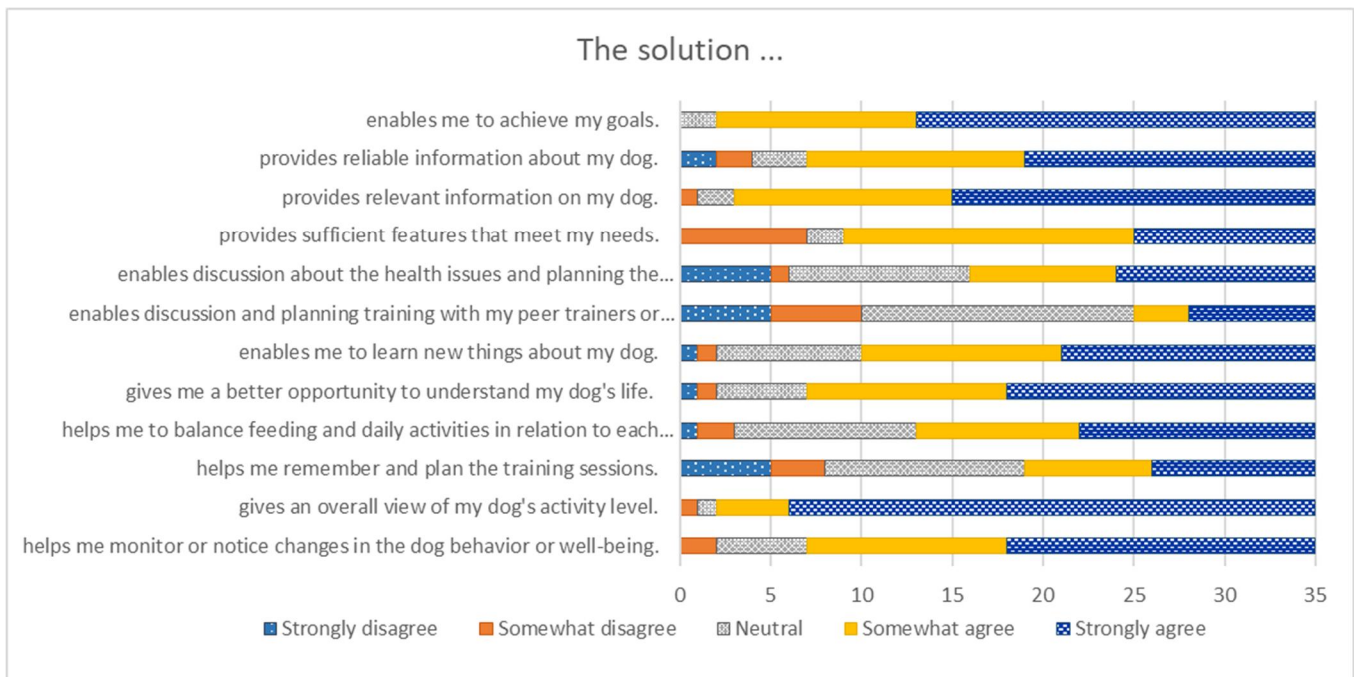
Figure 1. Utility and usefulness of dog's activity tracker and health monitoring device

User experience and usability

In general, the respondents were quite happy with the usability and user experience of the solution; the average in all of the statements in this category was above 4 (4 = somewhat agree). Especially, the solution was found to be *easy to use* (4.71 ± 0.52) and the visual presentation of the data was found to be *clear* (4.57 ± 0.65). In addition, respondents found the solution as easy to wear with *good ergonomics* (4.31 ± 1.02), and they felt they can *trust* the data and its presentation (4.29 ± 0.93); a few disagreed (as mentioned earlier, there were features that were not trusted, e.g., incorrect calorie count).

Using the solution was fun (4.43 ± 0.89) and the majority enjoyed using it (4.43 ± 0.95). Overall, almost all were happy with their solution (4.54 ± 0.82) and would recommend it or a similar solution to their friends or family (4.46 ± 1.09).

Respondents also commented (in the free text field) that they share experiences on the device on social media and give thanks to the user support of the device.

Added value

The most strongly agreed added value was that the solution inspires the respondents and keeps them interested in the dog's activities (4.37 ± 0.94). Many respondents felt the solution deepens their bonding with the dog (3.83 ± 1.36). This correlated with the motivation to understand the dog's feelings (r = .56, p < .001). Some respondents agreed that using the solution can make them a better dog owner (3.77 ± 1.17). However, whether using it makes their friends consider them to be an expert was undecided (most replying 3 = neutral, 2.91 ± 1.07).

The solution can give something to compare and talk about with the friends and family (3.69 ± 1.21) and it may even give some information of the dog owner's own activity levels in addition to the dog activity (3.54 ± 1.29).

Most positive and negative experiences

We asked the participants to write in their own words about their most positive and negative experiences on using the tracker.

Seeing the full report on daily activities including the rest, was reported as "eye opening". Several respondents mentioned that being able to monitor both the activity and the rest periods, and to be able to balance them, was useful and helped them to see the effect of proper activity and rest - - or the lack of it - on the dog's behavior. For example, if the dog did not have enough undisturbed sleep, "it acted up the following day". Several respondents explicitly commented that the tracker helped them to find a good level of activity (and rest) to keep the dog happy.

Changes in the activity or rest behavior was also used for noticing potential health issues. Other positive experiences included being able to find a good level of exercise to keep the dog fit and healthy, and to see if other people (dog sitter or family members) had already taken the dog out and make up for it if the goal had not been met for the day.

> *"It allowed me to find a good match for my dog of activity level to wear her out and keep her happy. I LOOOOOOOOVE that I can see and track how much she sleeps and if the dog sitter did in fact, take her out for walks."* (P28, Siberian Husky, female)

Negative experiences were mostly related to technical problems or missing features: the tracker was not fully waterproof (complained about by 11 respondents), did not include GPS, the tracker's quality was poor so that it broke too easily or the attachment mechanism did not keep it safely in place. Poor battery life and lost data was also mentioned a few times. There were also a couple of mentions on inaccurate information and late/slow delivery of the product. Eight respondents did not report any negative experiences.

Insights and impacts

Most of the insights were about understanding how much rest and activity the dog actually needs. This was also mentioned under the most positive experiences. There were several related comments such as: "learned how much exercise she needs in order to be happy and healthy and to be calm and sleepy in the evenings", or "allows me to find ideal amount of exercise she needs to be happy". Changes in the activity and rest also helped in noticing if the dog's health condition was getting worse, which alerted the dog owner to slow down in activity, adjust diet or contact the veterinarian.

> *"It also can alert me to slow downs in activity, specifically when at daycare, that could indicate pain or discomfort. It enables me to identify and react to issues quickly before they become major."* (P21, Mixed breed, female)

The tracker made it explicit for the dog owners to deeply understand the effect of the activity and the time they spent with the dog on the dog's quality of life, "to keep her happy" as several respondents expressed it. For example, one "learned she does much better when she gets regular time outdoors".

> *"I'm realizing that while it's not significant in my day, the little things I do with my dog, it really does make up his whole day."* (P22, Australian Shepherd, male)

Those who had tracked several dogs had seen how different they are by comparing their data. They expressed that this helped them to learn the dogs' individual needs. The tracker had also been helpful in monitoring recovery from injury and in seeing which approaches worked for separation anxiety and which didn't.

Overall, people felt the tracker had improved their understanding of the dog's needs, though a few commented the tracker did not affect their relationship, which had been great to begin with. Even if they already had focused on their dogs' wellbeing, they felt the tracker provided information the dog may not be able to communicate and gave confidence in interpreting things they had already observed. In return, learning more about the dog's needs improved their relationship. For example, several respondents mentioned spending more time together, "enjoy walking together", and "bond throughout the day". As one of the respondents commented, using the tracker to ensure enough play or walk time with the dog had not only improved the dog's life but also his/her own.

DISCUSSION

The results from both strands of the mixed method study corroborated and extended the findings from previous studies. In addition, our results are in line with the marketing of the devices for consumers on the market, i.e., dog owners, and the type of usage scenarios described on the activity tracker manufacturers' webpages. The main usage motivations were related to monitoring and balancing the amount of activity and rest, identifying changes related to health and wellbeing of the dog whether positive or negative, remote monitoring of the dog's activity, monitoring behavioral issues and effectiveness of their treatment, and supporting physical training and rehabilitation of dogs after surgery or injury.

The important impacts and insights gained included understanding the life and behavior of the dog more deeply and comprehensively as well as realizing the dependence of the dog's welfare on the owner's presence and time spent with the dog. This in turn affected the owner's behavior and actions, such as, adjusting the amount of exercise, play and rest or the amount of food given to the dog based on the data. Owners gained confidence by utilizing the data for the benefit and happiness of the dog, and felt content and happy when the decisions made provided support for the dog's physical and mental welfare, including social aspects as well. The survey respondents were asked about bonding with the dog and results indicated that the used solutions can deepen the bond. In addition, the respondents expressed that they wanted to understand their dog's feelings with the solutions. Interestingly, this is not directly supported by the used solutions, rather this type of inferences need to be made by the owner. Furthermore, dog tracker usage has impacts beyond the obvious health and physical activity related aspects. These are consequences of the dog owner's interest towards the dog and its happiness and welfare, and using the data to support this goal.

The results are on the other hand supporting and on the other hand contradictory to findings from prior research. First, the participants' motivations for using the tracker are in line with the expectations and wishes reported earlier [29, 28, 18]. Dog owners want to monitor the dog, especially when the owner is away, they are interested in the dog's welfare and expect the tracker to be useful in monitoring health, including both physical (e.g., recovery from illness and weight monitoring) and behavioral issues (e.g., separation anxiety). Further, our results showed that some of the concerns expressed earlier still pertain. There were some negative experiences and complaints about the reliability, durability, and battery life.

Second, our findings indicate that dog owners in fact are more interested in their dogs and do not solely rely on the tracker data. Rather they make inferences of the dog behavior based on direct observations, and corroborate and expand this knowledge and understanding with the tracker data. This contrasts previously reported fears that people would not interpret their pet's behavior correctly because they are

relying on the information provided by a monitoring device and not on the actual behavior of the dog [18]. The concern expressed by animal behavior experts [18] of validating the technology to ensure correct interpretations is actual and requires more work. Also in our study, there was one participant who reported getting invalid suggestions from the device: it had suggested that the owner "over exercised the dog just by talking a short walk" and that the dog "needs a bath to calm him down".

There are some limitations in our mixed method study. First, generalizability of the results is limited by at least two factors. The number of participants was relatively small and the most of the interviewees and questionnaire respondents were early adopters and early majority, i.e., positive in their attitudes towards technology [34]. These can create bias in the results that is shown as more positive perceptions than the general public. However, as the technology is still on the edge of penetrating to the mass market and reaching wider audience, we believe the results reflect the benefits that can be reached by using the trackers in best scenarios. It is also possible that our participants were more concerned of the welfare of the dogs than an average owner. This gives a challenge for design to reach and persuade also the less caring or less informed owners, and support and increase of their interest for dog welfare.

In human health and activity tracking market, the devices are already part of the mainstream culture. Not surprisingly, there are similarities in the motivations for using the devices with humans and dogs, for example, improved health and wellbeing [6]. There are also various pitfalls and reasons to abandon the technology after initial usage. For example, a mismatch between expectations and experiences in using the system is a common reason for abandonment [7]. Sometimes the device is successfully used for a specific purpose and it is no longer needed after the goal is met. We assume the same can happen with dogs, for example, in the case of tracking recovery from acute illness or medical intervention. There are also development needs that are similar in both, for example, the need to link the measurements with context information [6]. The present selected user group of active dog enthusiasts and early adopters had used the dog activity tracker for 11 months on average. More research is needed to find out motivations for long-term use as well as barriers and reasons to stop using the tracker.

The present work considered mostly the human perspective, though the owner's perception of the dog's welfare and happiness should not be underestimated. Further research is needed to address the animal's needs and perspective as reminded by Mancini et al. [21]. There were wishes for understanding the dog's feelings and getting better interpretations of their behavior. Current devices on the market are still quite simple and require human interpretation even though artificial intelligence and machine learning could in the near future enable more advanced solutions. For example, alerts of long-term changes that are hard to otherwise notice and linking the behavior with context or events could add value for welfare management and training As happiness of the dog is important for the owners, the dogs' happiness calls for basic research on dogs' emotions and development of methods, that enable the measurement and analysis of the dog's feelings.

To sum up, the happiness and welfare of the dog and the related issues are important for the participants of our study. They are willing and eager to spend time to understand their dog's behavior and life, they are willing to make changes based on what they learn, understand, and gain insights on. Finally, they feel happy when they perceive their dog to be happy.

CONCLUSIONS

This study indicates that the first priority motivation of the dog owners to purchase and use dog activity trackers was to get better understanding of the dogs' physical well-being. Participants in our study were mostly satisfied with the usability of the devices and the related services. Importantly, the owners were motivated to change their behavior in respect to the dog based on the insights gained from activity tracking. The tracker inspired the owners to spend more time with the dog and to be more observant to its behavior. In return, this had the potential to improve their relationship. The main underlying motivation to use monitoring technology was to support and ensure the welfare and happiness of the dog. The owners wanted their dogs to be happy, and perceiving the dog as happy made the owners happy.

REFERENCES

1. Alcaidinho, J. 2016. Canine behavior and working dog suitability from quantimetric data. In *Proceedings of the SIGCHI Conference Extended Abstracts on Human Factors in Computing Systems (CHI EA'16)*, 193-197. http://dx.doi.org/10.1145/2851581.2859023

2. Alcaidinho, J., Valentin, G., Tai, S., Nguyen, B., Sanders, K., Jackson, M., Gilbert, E., and Starner, T., 2015. Leveraging mobile technology to increase the permanent adoption of shelter dogs. *In Proceedings of the 17th International Conference on Human-Computer Interaction with Mobile Devices and Services (MobileHCI '15)*, 463-469. http://dx.doi.org/10.1145/2785830.2785861

3. Brown, D. C., Boston, R. C., and Farrar, J. T. 2010. Use of an activity monitor to detect response to treatment in dogs with osteoarthritis. *Journal of the American Veterinary Medical Association*, 237 (1), 66-70.

4. Bruno, E. A., Guthrie, J. W., Ellwood, S. A., Mellanby, R. J., and Clements, D. N. 2015. Global positioning system derived performance measures are responsive indicators of physical activity, disease and the success of clinical treatments in domestic dogs. *PloS one*, 10 (2), e0117094.

5. Byers, C.G., Wilson, C.C., Stephens, M.B., Goodie, J.L., Netting, F.E., and Olsen, C.H. 2014. Owners and pets exercising together: Canine response to veterinarian-prescribed physical activity. *Anthrozoös*, 27 (3), 325-333.

6. Choe, E. K., Lee, N. B., Lee, B., Pratt, W., and Kientz, J. A. 2014. Understanding quantified-selfers' practices in collecting and exploring personal data. In *Proceedings of the 32nd annual ACM conference on Human factors in computing systems*, 1143-1152. https://doi.org/10.1145/2556288.2557372

7. Clawson, J., Pater, J. A., Miller, A. D., Mynatt, E. D., and Mamykina, L. 2015. No longer wearing: investigating the abandonment of personal health-tracking technologies on craigslist. In *Proceedings of the 2015 ACM International Joint Conference on Pervasive and Ubiquitous Computing*, 647-658. https://doi.org/10.1145/2750858.2807554

8. Farm Animal Welfare Committee. The Five Freedoms. Retrieved August 31, 2018 from http://www.defra.gov.uk/fawc/about/five-freedoms/

9. Freil, L., Byrne, C., Valentin, G., Zeagler, C., Roberts, D., Starner, T., and Jackson, M. 2017. Canine-Centered Computing. *Foundations and Trends® in Human–Computer Interaction*, 10 (2), 87-164.

10. Grand View Research. 2018. Pet Wearable Market Size, Share & Trends Analysis Report By Technology, By Application (Identification & Tracking, Behavior Monitoring, Facilitation, Safety, Medical Diagnosis), And Segment Forecasts, 2018 - 2025.

11. Houpt, K.A. 2005. *Domestic Animal Behavior for Veterinarians and Animal Scientists*. Blackwell Publishing.

12. Houpt, K.A., Goodwin, D., Uchida, Y., Baranyiova, E., Fatjo, J., Kakuma, Y. 2007. Proceedings of a workshop to identify dog welfare issues in the US, Japan, Czech Republic, Spain and the UK. *Applied Animal Behaviour Science*, 106, 221-233.

13. Hsu, Y. and Serpell, J. A. 2003. Development and validation of a questionnaire for measuring behavior and temperament traits in pet dogs. *Journal of the American Veterinary Medical Association*, 223, 1293–1300.

14. Jukan, A., Masip-Bruin, X., and Amla, N. 2017. Smart Computing and Sensing Technologies for Animal Welfare: A Systematic Review. *ACM Computing Surveys*, 50 (1), 10:1-10:27.

15. Jumisko-Pyykkö, S. and Häkkinen, J. 2008. Profiles of the evaluators: Impact of psychographic variables on the consumer-oriented quality assessment of mobile television. In Proceedings *of the International Society for Optical Engineering (SPIE 6821)*. http://dx.doi.org/10.1117/12.765697

16. Ladha, C., Hammerla, N., Hughes, E., Olivier, P., and Ploetz, T. 2013. Dog's life: Wearable activity recognition for dogs. In *Proceedings of the ACM International Joint Conference on Pervasive and Ubiquitous Computing (UbiComp'13)*, 415-418. http://dx.doi.org/10.1145/2493432.2493519.

17. Ladha, C. and Hoffman, C.L. 2018. A combined approach to predicting rest in dogs using accelerometers. *Sensors*, 18 (8).

18. Lawson, S., Kirman, B., Linehan, C., Feltwell, T., and Hopkins, L. 2015. Problematising upstream technology through speculative design: The case of quantified cats and dogs. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '15)*, 2663-2672. http://dx.doi.org/10.1145/2702123.2702260

19. Lawson, S., Kirman, B., and Linehan, C. 2016. Power, participation, and the dog internet. *Interactions*, 23 (4), 37-41.

20. Lindsay, S.R. *Handbook of applied dog behavior and training. Volumes 1 & 2*. Blackwell Publishing, 2001.

21. Mancini, C., Lawson, S., and Juhlin, O. 2017. Animal-computer interaction: The emergence of a discipline. *International Journal of Human-Computer Studies*, 98, 129-134.

22. Mellor, D.J. 2016. Updating Animal Welfare Thinking: Moving beyond the "Five Freedoms" towards "A Life Worth Living". *Animal*, 6, 21, 1-20.

23. Meng, J. 2009. Origins of attitudes towards animals. PhD Thesis, School of Veterinary Science, University of Queensland, Australia.

24. National Research Council (US) Committee on Recognition and Alleviation of Distress in Laboratory Animals. 2008. Washington (DC): National Academies Press. Retrieved August 31, 2018 from https://www.ncbi.nlm.nih.gov/books/NBK4032

25. National Research Council (US) Committee on Scientific and Humane Issues in the Use of Random Source Dogs and Cats in Research. 2009. Washington (DC): National Academies Press (US). Retrieved August 31, 2018 from https://www.ncbi.nlm.nih.gov/books/NBK32671

26. Nelson, J. K. and Shih, P. C. 2017. CompanionViz: Mediated platform for gauging canine health and enhancing human–pet interactions. *International Journal of Human-Computer Studies*, 98, 169-178.

27. Oxford Dictionary of English. Retrieved August 31, 2018 from https://en.oxforddictionaries.com/english

28. Paasovaara, S., Paldanius, M., Saarinen, P., Häkkilä, J., and Väänänen-Vainio-Mattila, K. 2011. The secret life of my dog: Design and evaluation of paw tracker concept. In *Proceedings of the 13th International Conference on Human Computer Interaction with Mobile Devices and Services*, 231-240. http://dx.doi.org/10.1145/2037373.2037409

29. Paldanius, M., Kärkkäinen, T., Väänänen-Vainio-Mattila, K., Juhlin, O., and Häkkilä, J. 2011. Communication technology for human-dog interaction: Exploration of dog owners' experiences and expectations. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '11)*, 2641-2650. http://dx.doi.org/10.1145/1978942.1979329

30. Pons, P., Jaen, J., and Catala, A. 2017. Assessing machine learning classifiers for the detection of animals' behavior using depth-based tracking. *Expert Systems with Applications*, 86, 235-246.

31. Preston, T., Baltzer, W., and Trost, S. 2012. Accelerometer validity and placement for detection of changes in physical activity in dogs under controlled conditions on a treadmill. *Research in Veterinary Science*, 93 (1), 412-416.

32. Rehn, T. Keeling, L.J., The effect of time left alone at home on dog welfare. *Applied Animal Behavior Science, 129* (2011), 129-135.

33. Rooney, N. A practitioner's guide to working dog welfare. *Journal of Veterinary Behavior*, 4, 3 (2009), 127-134.

34. Rogers, E. M. 2003. Diffusion of Innovations, 5th ed., New York: Free Press

35. Valentin, G., Alcaidinho, J., and Jackson, M.M. 2015. The challenges of wearable computing for working dogs. In *Adjunct Proceedings of the ACM International Joint Conference on Pervasive and Ubiquitous Computing (UbiComp '15) and Proceedings of the ACM International Symposium on Wearable Computers (ISWC'18)*, 1279-1284. http://dx.doi.org/10.1145/2800835.2807925

36. Valldeoriola Cardó, A., Somppi, S, Törnqvist, H., Inkilä, L., Koskela, A., Myller, A., Kujala, M.V., Kumpulainen, P.S., Väätäjä, H., Surakka, V., Vainio, O. 2018. Evaluation of three activity trackers in quantifying activity levels of static and dynamic behaviors of dogs. In *Proceedings of Canine Science Forum (CSF'18)*, poster session.

37. Warren, B., Wakshlag, J., Maley, M., Farrel, J.T., Struble, A.M., Panasevich, M., and Wells, M.T. 2011. Use of pedometers to measure the relationship of dog walking to body condition score in obese and non-obese dogs. *The British Journal of nutrition*, 106, Suppl 1(S1), 85-89.

38. Weiss, G.M., Nathan, A., Kropp, J. B., and Lockhart, J.W. 2013. WagTag: A dog collar accessory for monitoring canine activity levels. In *Proceedings of the 2013 ACM Conference on Pervasive and Ubiquitous Computing (UbiComp'13)*, 405-414. http://dx.doi.org/10.1145/2494091.2495972.

39. Wigelius, H., & Väätäjä, H. 2009. Dimensions of context affecting user experience in mobile work. In *IFIP Conference on Human-Computer Interaction*. Springer, Berlin, Heidelberg, 604-617.

40. Yashari, J.M., Duncan, C.G., and Duerr, F.M. 2015. Evaluation of a novel canine activity monitor for at-home physical activity analysis. *BMC Veterinary Research*, 11:146.