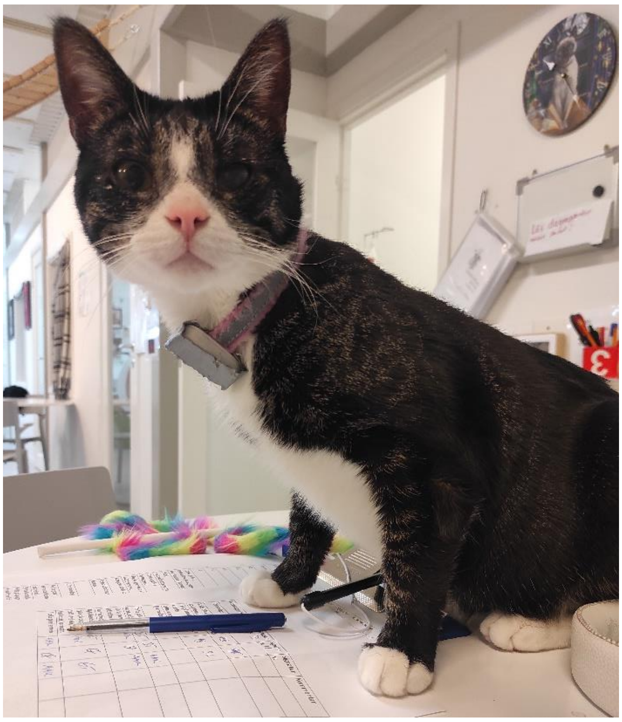

Validation of a cat activity monitor – with a focus on drinking and littering

Daria Ketrzynska

Independent project in Animal Science • 30 credits
Swedish University of Agricultural Sciences, SLU
Department of Clinical Sciences
Animal Science - Master's Programme
Uppsala 2023

Validation of a cat activity monitor

Validering av ett aktivitetshalsband för katt

Daria Ketrzynska

Supervisor:	Anna Bergh, Swedish University of Agricultural Sciences, Department of Clinical Sciences
Examiner:	Odd Höglund, Swedish University of Agricultural Sciences, Department of Clinical Sciences

Credits:	30 credits
Level:	A2E
Course title:	Independent Project in Animal Science
Course code:	EX0870
Programme/education:	Animal Science - Master's Programme
Course coordinating dept:	Department of Animal Breeding and Genetics
Place of publication:	Uppsala
Year of publication:	2023
Cover picture:	Daria Ketrzynska
Copyright:	All featured images are used with permission from the copyright owner.
Keywords:	accelerometer-based activity monitor, activity, physical activity, monitor collar, cat, feline, validation, diabetes, drinking, urination

Swedish University of Agricultural Sciences
Faculty of Veterinary Medicine and Animal Science
Department of Clinical Sciences

ABSTRACT

Early detection of diseases and injuries in animals is crucial for their health and well-being. Early diagnosis can be assisted by objective registration of different types of physical activities or behaviour patterns. Monitoring specific parameters, such as changes in activity levels or habits, could serve as an indicator of underlying health issues. It can be challenging for pet owners to notice subtle changes in those characteristics at an early stage. It becomes more difficult in the case of parameters of a low frequency of occurrence, such as drinking and littering behaviours. Hydration status is extremely important in cats and changes in drinking and littering patterns could be early symptoms of potential disorders, in particular diabetes mellitus.

There is a noticeable increase in owners' awareness about the physical and mental health of their pets. With a growing demand for higher standards of tools to assess animals' everyday habits, more technologies are being developed. Activity monitors utilizing accelerometers provide broad and continuous measures of physical activity, that enable remote and non-invasive monitoring of an individual's actions.

The aim of this study was to validate the registrations of an activity monitor. Specifically, the study aimed to assess the effectiveness of the activity monitor in detecting drinking and littering activities, which might suggest underlying health issues. To monitor these activities, this study used an activity monitor equipped with an accelerometer and attached to a collar. The validity and effectiveness of the activity monitor were established by comparing the measurements obtained from the activity collar to video recordings from the motion sensor camera.

For forty-eight days, activity data on drinking and littering actions were collected from a single adult cat. Descriptive statistics were performed to summarize the main findings of the dataset to obtain key results. From the total of 5989 recordings registered by the motion sensor camera, 671 recordings containing actions of drinking and littering were selected for further analysis. Accordingly, 53 recordings were extracted from the activity monitor. This study found no correlation between the data obtained from the activity monitor and the video observations from the motion sensor camera. Further research is needed to investigate the reasons behind this lack of agreement and to improve methodologies for monitoring feline activities using activity monitors.

Despite underwhelming findings, it should not rule out all potential applications in monitoring feline behaviors, managing health disorders, and promoting overall health remain promising.

Keywords: accelerometer, accelerometer-based activity monitor, activity, physical activity, monitor collar, cat, feline, validation, diabetes, drinking, urination

Table of contents

List of tables

List of figures

Abbreviations

AM	Activity Monitor
BGC	Blood Glucose Curve
NSAID	Nonsteroidal anti-inflammatory drug
OA	Osteoarthritis
SLU	Swedish University of Agricultural Sciences

1. Introduction

Early diagnosis of diseases and injuries in animals can be aided by objectively registering various types of physical activity and behavior. Monitoring specific characteristics, such as changes in activity levels or alterations in habits, allows for the detection of potential signs of illness or pain, enabling quick intervention and care.

Diabetes mellitus is a common endocrinopathy in felines that appears to be increasing in prevalence (Aspinall, 2012; Cannon and Forster-Van Hijfte, 2006; Cooper et al., 2020). The main methods to monitor this disorder are clinical and physical examination, together with hematology and biochemistry tests, usually along with home monitoring of capillary blood sampling with a glucose meter. Detecting early signs of diabetes is important for quick diagnosis, intervention, and treatment, all of which are crucial for an animal's overall health and well-being. Some of the first symptoms of diabetes in cats are polydipsia (increased thirst) and polyuria (increased urination) but pet owners usually find it difficult to detect changes in the frequency of drinking and littering (Dulaney et al., 2017).

An accelerometer is a non-invasive, wearable device that allows to track changes based on movement and position. This approach is becoming increasingly popular in animal science research for its capability to give broad, precise, and continuous measures of physical activity (Karas et al. 2019; Lascelles et al., 2008, Watanabe et al., 2005). It provides important insights into animals' daily routines, behaviors, and movement patterns.

This work expands on the potential of using activity collars with accelerometers to monitor predefined activity categories commonly observed in cats with diabetes. The specific aim of this experiment was to validate the registrations of an activity monitor designed for cats, specifically two predefined activity categories - drinking and litter box usage. The efficacy and precision of the monitor were compared to video recordings of the same activities captured by the motion sensor camera. The null hypothesis predicates absence of significant correlation between the activities registered by the activity monitor and their corresponding videos.

1.1 Aim and research questions

The general aim of this pilot study was to validate the registrations of an activity monitor designed for cats. Simultaneously, the specific aim was to assess the accuracy of the activity monitor in detecting drinking and litter box usage activities. Tracking deviations from established norm could allow for early detection of disorders, such as feline diabetes. The effectiveness and precision of the monitor were compared to video recordings of the same activities.

The objective was to develop a non-invasive tool for early identification and management of feline diabetes by comparing the efficacy and accuracy of the monitor to video recordings of the same activities.

The null hypothesis for this study is that there is no significant correlation between the activities registered by the activity monitor and the corresponding videos.

The research questions are:

- What is the potential of using activity collars with accelerometers to monitor predefined activity categories specifically related to drinking and litter box usage?
- How well does the activity recorded by the activity monitor match the activity observed from video recordings? What is the correlation?

2. Literature review

2.1 Cat activity monitoring

2.1.1 Accelerometer

An **accelerometer** enables tracking changes based on movement and orientation - if something is changing directions, how quickly it is moving up or slowing down, the intensity and frequency of its movements, and other related parameters (Kooros, 2021). It measures **acceleration**, which is the rate at which velocity changes with time, both in terms of speed and direction.

The common structure of an accelerometer involves a small proof mass attached to a device that allows it to react correspondingly to changes in acceleration. The displacement of the proof mass is measured by sensors such as piezoelectric crystals or capacitors and after that expressed in gravitational units relative to the device's standpoint (Karas et al., 2019). Accelerometer data is processed using a variety of algorithms into summaries that can be combined at different temporal levels (e.g., minutes, hours, or days) and can have a variety of tags (e.g., steps, calories, exercise, etc., in animal research e.g., activity, play, grooming, etc.) (Karas et al., 2019). There are different types of those devices but the most used is the **3-axis accelerometer** which has three acceleration sensors positioned in three perpendicular axes, typically labelled as x, y, and z (Chapa et al., 2020). This makes it possible to determine the dynamic body's acceleration. As monitors have advanced, they are now frequently fitted with a variety of supplemental sensors, such as a gyroscope used to detect deviation of an object from its desired direction. Other additional sensors like magnetometers and barometers can provide supplementary information about orientation, and environmental conditions, enabling a broader understanding of animal's activity.

Accelerometers are used in mobile devices to detect orientation, in cars to measure speed, in sport and fitness to measure movement, to detect mechanical issues in industrial equipment, or in aerospace to monitor the performance of aircraft and such. In human medicine, accelerometers are used for research on i.e., the impact of age on physical activity (Wolff-Hughes et al., 2018) or functional recovery after surgery (Cook et al., 2013). In animal science, there is a significant increase in published studies using accelerometers in research. Further analysis on this topic will be presented in subsequent sections of this work.

Activity collars, which use the accelerometer technique, enable tracking changes based on movement and orientation. The accelerometer technology embedded in activity collars provides a means to monitor and analyse the dynamic behavior of animals, allowing for a deeper understanding of their activities and behaviors.

Wearable accelerometers offer thorough, accurate, and ongoing measures of physical activity in humans (Karas et al., 2019) and animals (Hansen et al., 2007; Jones et al., 2014; Lascelles et al., 2008, Ringgenberg et al., 2010; Robert et al., 2009’ Yamazaki et al., 2020). That allows researchers to identify and compare critical periods of movement, which provides insights into the physical activity of an individual. Accelerometers are frequently integrated into portable devices because they are physically small and lightweight (Zhou and Hu, 2008) which improves the comfort and practicality of long-term monitoring for animals. Such monitors are usually worn on an animal’s limb, as an ear tag, or as a collar attached around the neck. There is a recommendation that monitoring devices should not weigh more than 5% of the body mass of an animal (Coughlin and van Heezik, 2014; Dickinson et al., 2020). However, instruments weighing less than 3% BM, according to simulation, may nonetheless influence the movement patterns of individuals. Coughlin and van Heezik (2014) demonstrated that domestic cats wearing heavier collars (>3% BM) reduced their activity compared to when they wore lighter collars. This study modified the suggestion on the weight of monitors to below 2% body mass.

There is a current increase in awareness among pet owners about the importance of monitoring their animals' physical activity. This led to a rise in a variety of gears introduced to the market that allows to increase the well-being of companion animals. Pet owners are recognizing the benefits of using activity collars as a tool to understand their pet's daily behavior patterns, activity levels, and health status since these are convenient and non-invasive tools to track and monitor animals’.

With developing technology such devices are becoming more advanced. Some models can monitor parameters like heart rate, respiratory details, sleep patterns, temperature, and calories burned. The integration of advanced technologies, like machine learning and artificial intelligence, further enhances the analysis of animal activity. These technologies enable automated data processing, pattern recognition, and the extraction of meaningful details from data.

Cats have unique activity patterns and behaviors compared to other animals, and activity collars should be designed specifically to monitor and track these feline-specific activities. This includes behaviors such as grooming, scratching, climbing, and littering. It might be especially challenging considering their tendency to be more active during nighttime and their outdoor behaviors. In these cases, activity monitors could be advantageous tools.

2.1.2 Studies on reliability and validation of activity monitors in cats

In recent years, there has been a significant increase in published studies utilizing accelerometers in animal science research. These devices have gained popularity due to their low cost, non-invasiveness, and ability to provide quantitative measurements of activity. Various studies have applied accelerometers to study different animal species and behaviors. Brown et al. (2013) use accelerometers to observe free-ranging wildlife, while Barwick et al. (2018a, 2018b, 2020) focused on measuring posture and activity states in sheep. In Robert et al. (2009), the classification of lying and standing activities using accelerometers in cattle demonstrated excellent correlation with video observations, with a 99.2% correlation for lying and a 98.0% for standing. Similarly, Ringgenberg et al. (2010) achieved accurate identification of different postures in sows using accelerometers, with values correctly identified above 90% for all postures. In a study by Barwick et al. (2018b), the effectiveness of different accelerometer placements (ear, neck, and leg) in differentiating locomotion in sheep was investigated, revealing that the ear placement demonstrated high accuracy in predicting grazing (94%), standing (96%), and walking (99%) events, making it the most suitable placement for identifying basic sheep behaviors.

Additionally, accelerometers were used in dogs to monitor disorders that decrease mobility (like osteoporosis or OA), to evaluate the efficacy of pain management after receiving NSAIDs medication treatment (Lascelles et al., 2007; Lascelles et al., 2008, Andrews et al., 2015), and to compare postoperative activity of dogs undergoing laparoscopic and open ovariectomy (Culp et al., 2009).

Chapa et al. (2020) conducted a study to explore the use of accelerometers for welfare and health evaluation in cattle and pigs based on the Welfare Quality® assessment guidelines. The study demonstrated that accelerometers showed high accuracy in most parameters for movement and resting behaviors, which could serve as indicators of compromised welfare and health. By tracking these parameters, accelerometers could be used as an early warning system to identify specific factors that pose risks to an individual's well-being.

Another notable study by Jones et al. (2014) investigated the use of accelerometers as a tool to secure animal welfare in a group of shelter dogs. The study aimed to determine if activity levels measured by accelerometers could serve as an indicator of physiological and behavioral stress. The findings highlighted the potential of accelerometer data in monitoring and controlling stress levels in shelter dogs, thereby reducing behavioral issues, and improving the chances of a successful adoption.

Watanabe et al. (2005) conducted one of the earliest research into the potential of using accelerometer devices in cats. The study aimed to characterize different behaviors efficiently using an activity monitor. While the study recorded high accuracy for behaviors such as drinking (100%) and eating (68.4%), data on elimination was not captured, which is one of interest in this project.

Lascelles et al. (2008) evaluated the relationship between cat movement recorded on video and information from an accelerometer-based activity monitor. The study found a high correlation (adjusted R^2 0.95) between the data collected from the harness and collar accelerometers from 3 cats. However, the harness initially caused a decrease in mobility, likely due to discomfort. The experiment compared 432 hours of activity data from computer-analyzed footage and simultaneously acquired accelerometer data. Overall, there was a 0.82 correlation (adjusted R^2) between accelerometer data and distance travelled. Researchers also aimed to evaluate the daily and weekly changes in activity, as a tool to monitor pain relief in disorders that decrease mobility.

Andrews et al., (2015) aimed to quantify the degree of inter-individual variance by validating accelerometers in 13 cats. Currently, this study has the biggest number of experimental units in research on cat activity using accelerometers. The study concluded that accelerometers could be used to precisely and remotely measure the time spent active in domestic cats. It also emphasized the significance of considering inter-cat variation and using individuals as their own control when evaluating changes in activity levels.

Activity monitors are attracting attention for the early detection of different disorders and monitoring animal welfare. While present project specifically focuses on the use of an accelerometer to monitor key activities for diabetic cats (drinking and litter box usage), similar approaches have been explored in the context of other disorders.

Osteoarthritis (OA) is a common disorder in older cats, causing chronic pain and reduced mobility (Stadig et al., 2016). Currently, there is no validated systems for measuring pain in cats with OA (Lascelles et al., 2007). Researchers have investigated various tools to assist in pain assessment. For example, Brown et al. (2010) explored the use of activity monitors to detect changes in activity levels in dogs with OA treated with carprofen or a placebo. Lascelles et al. (2007) found that owners' subjective assessments combined with the use of activity monitors were valuable in identifying pain-related behaviors and assessing the response to NSAID treatment in cats with OA at home. The objective data obtained from accelerometer-based activity monitors hold the potential to verify subjective assessment methods and enhance the clinical evaluation of chronic pain in cats.

Additionally, studies have examined the use of accelerometers to detect oestrus-related locomotor frequency changes in cats (Andrews et al., 2022).

Overall, these studies highlighted growing interest and potential of applications of accelerometers in animal science research, which provides valuable insights into activity monitoring, welfare assessment, and the detection of various diseases.

There have been studies at Swedish University of Agricultural Sciences (SLU) conducted to validate cat activity monitor with predefined categories of activities. Two bachelor theses and one master’s thesis investigated registrations from cat activity collars and their correlation with activity observed through video analysis (Devlin and Olausson, 2018; Arvidsson and Spence, 2018; Mathiasson, 2019). While those student theses utilized similar tool, the specific objectives and details of those studies differ from the current research. Notably, neither drinking nor elimination behaviors were examined independently in any of mentioned projects.

In their pilot studies, Devlin and Olausson (2018), as well as Arvidsson and Spence (2018), aimed to evaluate whether an accelerometer-based activity monitor can effectively quantify and categorize feline activity. Arvidsson and Spence (2018) recorded two cats, Katt 1 for approximately 78 minutes, and Katt 2 for 108 minutes. The study combined eating and drinking as one category for video analysis, with Katt 1 spending 7% of recorded time on eating and drinking, and Katt 2 for 11,5%. However, there were no records regarding drinking only. No data were registered for elimination activities, neither by the activity monitor nor the camera. In Devlin and Olausson's (2018) study, used activity monitors were unable to register elimination or drinking activities in cats, and as a result, no data regarding these behaviors were captured. By the inclusion of these categories in the study authors proposed important topic and area for future research.

In Mathiasson's (2019) study, a total of five hours and 40 minutes of recordings of six cats were collected. The activity monitor used in the study registered elimination and drinking activities in some cats. However, it is important to note that there were no corresponding video records of these activities to confirm the occurrence, that is why those entries were fully excluded from the analysis.

A common conclusion was recognition of a great potential of using accelerometers in evaluating patients and treatments. These theses collectively contributed to the understanding of the potential of using accelerometers in assessing cat activity and provided insights into the limitations and possibilities for future studies in this field.

Having examined the existing literature on activity collars in cats, it is crucial to assess the reliability of these devices through dedicated validation studies. Validation is necessary to assure precise measurements, allow for comparison, and increase confidence regarding the results of studies. It provides a base for accurate results, improving research and expanding knowledge of feline behavior, health, and wellbeing. Comparing accelerometer data with direct observation of the animal's behavior can help validate the measurements.

An increased of number owner-friendly and commercialized accelerometers are available on the market, such as PetPace (https://petpace.com/), Whistle (https://www.whistle.com/), and Moggie designed especially for cats camer. Currently, the best validated device used in research on physical activity of animals is Actical®, that is already widely used in human activity monitoring (Belda et al., 2018). The goal of Belda et al. (2018) study was to determine whether the activity output from Actical® and Actigraph, validated in dogs, matched the activity output from commercially available the PetPace device and observed a moderate correlation of 0.59. Yamazaki et al. (2020) used Plus Cycle®, a new monitor designed for cats, and compared it to Actical®, Results shown correlation of a 0.89

total activity and 0.78 activity intensity for Plus Cycle®, and a strong correlation of 0.89 with Actical®.

The growing interest in assessing everyday habits of companion animal has increased the need to acquire objective assessments of activity at home. This was demonstrated in a study by Hansen et al. (2007), where the relationship between movement and motion captured on film and accelerometer-measured activity in healthy dogs was determined, highlighting the value of accelerometers as useful devices for objective, ongoing physical activity monitoring in an everyday context. The study showed excellent estimates of activity with Spearman correlations ranging from 0.71 to 0.93 for all comparisons with movement distance and duration when accelerometers were placed on eight different locations on the body. This enables a better understanding of an individual's movement patterns, behavior, and general health in an everyday context.

2.2 Feline diabetes

Diabetes mellitus is an endocrinopathy caused by a complete or partial shortage of the hormone insulin, which is crucial for controlling blood glucose levels (Aspinall, 2012; Cannon and Forster-Van Hijfte, 2006; Cooper et al., 2020). It is characterized by hyperglycaemia (high levels of blood sugar).

Depending on the literature, diabetes mellitus is usually divided into four different types, but the most common ones are types 1 and 2. In type 1 diabetes the body is not producing insulin which is causing the glucose blood level to rise (American Diabetes Association, 2013). The body’s immune cells strike the pancreas, specifically beta cells in the islet of Langerhans responsible for the secretion of insulin (Cooper et al., 2020). It is rarely observed in cats, but more often in middle-aged dogs. Type 2 diabetes is non-insulin dependent, meaning that the body makes insulin but doesn’t respond to it correctly (American Diabetes Association, 2013). Due to high amounts of blood sugar, insulin is maintaining the stability of those levels, resolving in reduced activity of beta cells and decreased secretion of insulin. Diabetes type 2 is more common in cats compared to dogs.

Environmental risk factors for cats include advancing age (usually five years old and more), male gender, obesity, neutering, pharmaceutical treatment, lack of physical activity, and indoor confinement (Rand et al., 2004).

In cats, there are three early symptoms of diabetes:

- polyuria (PU) - increased urination,
- polydipsia (PI) - increased thirst,
- weight loss (Aspinall, 2012; Cannon and Forster-Van Hijfte, 2006; Cooper et al., 2020).

Other observed signs include lethargy, changes in behaviour, polyphagia (increased hunger), and glycosuria (presence of glucose in the urine) (Cooper et al., 2020). It is important to remember that those signs could be symptoms of other diseases in cats.

Depending on the type of diabetes the patient suffers from, treatment usually involves insulin therapy, antidiabetic medications, and lifestyle changes. Recommendations include a healthy diet, regulation of food intake, weight loss, exercise, and pharmaceutical care (Cannon and Forster-Van Hijfte, 2006; Cooper et al., 2020). For diabetes to be managed effectively, lifelong dedication and compliance are necessary.

As a result of urbanization and domestication cats have changed from hunting animals that consumed protein-rich prey to more sedentary animals that ingest commercially produced diet high in carbohydrates (Slingerland et al., 2009). Consequently, the pancreas cannot secrete such high amounts of insulin to continuously lower blood sugar levels. Change of diet is a very important part of maintaining feline diabetes and it is recommended to feed it a naturally high protein low sugar diet.

2.2.1 Drinking and urination habits in cats

Cats naturally have a relatively low desire to drink, thus they are slow to react when their level of hydration changes (Buckley et al., 2011). The amount of water a cat should drink in a day may vary based on factors like age, diet, weight, and activity levels. However, there is no consensus on a definition of adequate water intake or optimal hydration in cats (Zanghi, 2017).

One of the objectives of Robbins et al. (2018) study was to determine if vessel that the water was, and its general presentation, influenced daily fluid consumption. The average water intake came up to 27.483 ml/kg/day for still water, 26.327 ml/kg/day for circulating, and 26.137 ml/kg/day for free-falling. It was concluded that water bowl type had no significant effect on water intake. Depending on circumstances, these values could be considered representative of the average water intake in cats.

Further, the diet greatly effects daily water consumption (Bradshaw et al., 2013). Dietary moisture has a major influence on the amount of water consumed daily and directly affects the percentage of water consumed by drinking (Zanghi, 2017). Cats on a wet food diet obtain a substantial amount of moisture through their food, resulting in lower water intake from drinking (Zanghi, 2017; 2018). Wet or raw diets, which typically contain over 75% moisture, tend to reduce the cat's reliance on drinking water (Buckley et al., 2011). The findings of Zanghi et al. (2018) study showed that consumption of nutrient-enriched water from wet food increased the amount of water consumed through drinking which is strongly associated with changes in the total water intake and diluted urine.

On the other hand, cats fed dry food consume less moisture from their diet and compensate by drinking more water (Zanghi, 2017; 2018). However, it's important to note that even though cats on a dry food diet may increase their voluntary drinking by nearly six times, they still consume approximately 30% less water overall compared to cats on a wet food diet (Buckley et al., 2011).

Generally, fresh water should always be accessible for an individual to drink. To encourage drinking additional measures could be applied:

- increased number of drinking bowls,
- adjusted characteristics of the bowl itself, such as material (ceramic/glass), width, depth,
- frequent refilling with fresh water,
- adequate distance between bowl and litter box,
- added flavouring, such as tuna, chicken broth (all unsalted),
- adjusting dietary sodium content to stimulate drinking (Zanghi, 2018).

Setting a daily voluntary water consumption goal for diabetic cats is not achievable (Sparkes et al., 2015). To monitor the daily water intake in diabetic cats, the simplest method is to use a measuring cup and compare the water weight at the beginning of the day with that after 24 hours, as suggested by Mitchell (2023) and Robbins et al. (2018). Another tool useful to monitor water intake would be a smart fountain or water bowl. These devices can weigh the remaining liquid, enabling the monitoring of a cat's daily hydration levels. Any deviations from the recommended water intake should be simple to trace. However, it is important to note that this weighing may not be applicable for outdoor cats, as their access to multiple water sources and potential water consumption outside monitored area could lead to inaccurate measurements.

In cats with diabetes, the presence of insulin resistance or inadequate insulin synthesis prevents the body from correctly using glucose. Consequently, glucose that remained in the bloodstream causes hyperglycemia and osmotic imbalances. To counteract this, water is drawn from cells and tissues into circulation, resulting in an increased need to drink more (Cornell Feline Health Center, 2018).

When the endocrine system fails to effectively maintain blood sugar balance, the kidneys take on the main role of reducing glucose levels by increasing urination and eliminating excess glucose from the bloodstream through the process known as glucosuria (Reusch, 2015). Diabetic cats frequently experience increased thirst due to dehydration and will drink more water to replenish fluid loss. However, even with increased fluid intake, diabetic cats may still face dehydration due to the excessive loss of fluids during urination, which often occurs because of diluted urine. It can appear as a common pattern of polyuria, dehydration, and polydipsia.

Several common comorbidities, such as chronic kidney disease, induce a steady loss of body fluid, and monitoring of hydration status of the cat, especially senior, is crucial (Ray et al., 2021).

Cats with polydipsia may also potentially show signs of inappropriate urination because access to toileting sites becomes limiting with the increased need to eliminate (Bradshaw, 2012).

It is crucial to pay attention to both drinking and elimination patterns in cats with diabetes. Monitoring urination is challenging but observing the litter box can provide valuable information, such as the frequency of elimination, and the size and colour of litter lumps. Some litter boxes have built in scales, which could allow to measure urine output.

Characteristics of a satisfactory littering area for a cat include a suitable number of litter boxes filled with custom substrate. The area should be away from feed, quiet and hidden, and without potential threats (Bradshaw, 2012). However, it is important to mention that these characteristics apply mostly to indoor cats, as outdoor cats may have different preferences and behaviors regarding littering habits.

2.3 Monitoring of feline diabetes

Initial diagnosis of diabetes in cats consists of clinical and physical examination, together with haematology and biochemistry tests (Aspinall, 2012; Cannon and Forster-Van Hijfte, 2006; Cooper et al., 2020). In ISFM Consensus Guidelines, Sparkes et al. (2015) explained the timeline of diagnosis of feline diabetes. It starts with an evaluation of the blood glucose curve (BGC) measured over the span of 12 hours (Reusch et al., 2006). During that period, blood samples are taken every 2 hours to detect elevated blood glucose levels. Initial BGC is required to detect the nadir and degree of blood glucose fluctuation. Additionally, serum fructosamine levels are often assessed alongside the BGC, providing a broader overview of average glucose regulation over the previous weeks, without influence of short-term stress hyperglycemia (Sparkes et al., 2015). Additional tests could be conducted, such as urinalysis to detect the presence of glucose in the urine (glucosuria). Regular blood panel testing may be also necessary to establish baseline results and determine the appropriate insulin dosage for cats diagnosed with diabetes (Cooper et al., 2020). The results of these tests are discussed with a veterinarian, and an individualized plan for further treatment, management, and follow-up visits is established.

Regular monitoring is essential for effective management of diabetes in cats. It relies on regular evaluations and owner's awareness of clinical signs (Reusch et al., 2006). This includes daily observations of behaviour, water and food intake, urine output, and weekly measurements of weight and body condition. When a cat is considered stable, BGS should be repeated every 3 to 4 weeks, and it is recommended to run a full blood panel test every 3 to 6 months to assess general health and organ function (Sparkes et al., 2015). The frequency of testing may vary depending on the individual cat's condition and recommendations of veterinarian.

Due to characteristics of most cats, hospitalization and repetitive blood sampling (however gentle) may cause the concentration of blood glucose to be significantly influenced by stress or refusal to eat (Casella et al., 2003; Reusch et al., 2006). Therefore, data produced from in-clinic BGC may not be entirely accurate resulting in incorrect judgment of the cat’s condition, it is important to consider these aspects when interpreting blood glucose results.

Frequent visits to veterinary clinics for managing chronic disorders can be challenging, particularly for cats that are known for being demanding patients. To minimize stress and protect their welfare during veterinary visits, collective efforts are made. In order to elevate health and quality of life of companion animals, veterinary researchers are incorporating combination of standard in-office evaluations with assessments at home (Hansen et al., 2007), resulting in more comprehensive understanding of an individual. This approach is particularly valuable since the duration of time spent at home is typically longer than that spent in a veterinary clinic (Lascelles et al., 2008).

In human medicine, self-monitoring of diabetes is commonly done using portable glucose meters. Similar technology has been introduced in veterinary science (e.g., AlphaTRAK) and is used to manage diabetes in companion animals with equipment validated for specific species. Glucose meters are simple to use, require a little sample volume, deliver results quickly, and are less distressing. Because cats are prone to stress hyperglycaemia, glucose meters have been recognized as a more effective and safer approach for assessing glycemic conditions (Cannon and Forster-Van Hijfte, 2006; Sparkes et al., 2015). Therefore, it can facilitate management of feline diabetes and improve the monitoring of blood glucose levels in cats (Kang et al., 2015). Capillary blood sampling is done using blood from capillary or marginal ear veins (Sparkes et al., 2015). Capillary blood glucose check is recommended twice a week or when concerned about the wellbeing of the cat (Reusch et al., 2001; Reusch, 2015; Sparkes et al., 2015).

2.3.1 Activity monitors in feline diabetes

Currently, there are no studies that used activity monitor after diagnosis of feline diabetes or during the treatment.

Accelerometers can contribute to diagnosis and management of diabetes in cats mostly by allowing to monitor activity levels overall. Regular physical activity can help with weight control, tone of muscles, better insulin sensitivity, while simultaneously aid in the regulation of blood sugar levels (Slingerland et al., 2009). By monitoring cat’s activity patterns, owner could assure that individual is getting enough exercise, which overall helps to control diabetes better. Additionally, data from accelerometers can be used as a basis for behavior or activity patterns of an individual. Any deviations or changes from the recognized norm could signal changes in blood sugar levels or possible risks to health because cats with well-managed diabetes should behave and engage in normal levels of activity (Cornell Feline Health Center, 2018).

Secondly, some monitors can categorize and track activities important to control in diabetic cats such as frequency of visits to the water bowl and litter box.

While the use of accelerometers to monitor drinking behavior in cats currently lacks research, exploring the application of this technology in other species can provide valuable insights and inspire future studies. For instance, a pilot experiment conducted by Williams et al. (2019) investigated the feasibility of using head-neck position and activity to detect and record drinking behavior in beef cattle. The study demonstrated that neck-mounted triaxial accelerometers accurately classified drinking behavior from standing (head up) with 100% accuracy. These findings highlight the potential of accelerometers to increase awareness of drinking habits and ensure that their water consumption needs are met.

Comparing accelerometer data before and after a specific treatment can provide information on the effectiveness of management of individual to owner and veterinarian.

3. Materials and methods

3.1 Literature search and roles in experiment

The term “observer” used in this study refers to the researcher and author of this text. As the primary investigator and data collector, the Observer played an active role in observing and analysing performed activities.

To study background information a lot of effort was put into finding relevant publications. The main search engines used for finding scientific literature were Web of Science, Google Scholar, and PubMed. Rest of materials was found in three veterinary textbooks in university library.

Search keywords included: accelerometer*, activity, "activity monitor", cat*, feline*. Literature search using keywords was challenging due to limited research on using activity monitors in cats and almost none in validating this device as a diagnostic tool in feline health.

Total reference list came up to 47 positions regarding different aspects included in this study. Three studies on validation of activity monitors in cats were given the most attention (Andrews et al., 2015; Lascelles et al., 2008; Watanabe et al., 2005).

Some information was added after email correspondence with activity monitor provider.

Figure 1. Experimental unit (Skymning) with activity monitor

3.2 Materials

According to Swedish legislation, ethical approval was not required for this type of study. Animal guardian consent was signed and stored.

The study was conducted in a cat shelter. The experiment covered one individual, called further “experimental unit”. The cat was a castrated, domestic shorthair male that weighed 5.5 kilograms. Its age was assumed to be around 3 years, but little was known about its history because he was found as a stray kitten. The individual had eye problem that required medication but other than that he was clinically sound before and during the experiment. Its health conditions were not a contraindication to the use of the selected methods.

3.3 Husbandry and feeding

The experimental unit shared the space with 2 to 4 cats. This number fluctuated due to adoptions, veterinary treatment, and shelter management. Dynamic between individuals was not intense, there was no conflicts or hierarchy fights observed or known by staff.

The size of the shelter room was 2,30 x 1,90 meters. In it there were feeding and drinking bowls, litter boxes, cat tree, and enrichment such as shelves and toys.

Cats were fed three times a day. On May 17th, 2023, the feed plan was changed from 3 to 2 portions a day, which resulted in altered water intake (discussed later). The kibble itself was also changed from Mjau to Royal Canine, specifically to Savour Exigent.

Before May 17^{th}			**After May 17^{th}**	
Time of feeding	8:30	25g dry food + 50g wet food	8:30	50g dry food + 50 g wet food
	14:00	50g wet food	19:00	50g dry food
	19:00	50g wet food		

Table 1. Plan of feeding during the experiment

Cats were always provided at least 2 bowls of water. Water was additionally changed twice per day to keep it fresh. Litter boxes were cleaned frequently. Additionally, boxes and litter were changed completely once a week.

This experiment was observational, and no direct interventions were added other than paying closer attention to water bowls.

3.4 Pilot study

Activity monitor

For this study collar manufacturer company kindly lent out one activity monitor developed specially to measure cats' activity.

This activity monitor is marketed as an option for pet owners to get an insight into animal's daily pattern. It guarantees to collect data immediately, 24 hours a day and send it to owner's phone into compatible app (Moggie.me, 2023).

Monitor was equipped with the 3-axis accelerometer and gyroscope. Its sensors take 150 measurements of movement per second. For these devices to be commercially capable, data must be collected, processed, and analysed simultaneously with data gathering (Barwick et al., 2020). It weighed 8 grams, which is according to Coughlin and van Heezik (2014) suggestions.

Figure 2. Activity monitor

The battery of this device is expected to last 3 to 4 weeks and can be charged with USB-C cable.

For safety measures and to avoid getting it wet, monitor was taped around. Equipment was charged fully, attached to a standard pet collar, and placed ventrally on the individual.

The activity monitor was connected via Bluetooth to wireless base. The base was transmitting data to a data server through stable internet connection.

As the animal moved or engaged in various activities, the triaxial accelerometer recorded shifts in acceleration. Algorithms were integrated into the activity monitor software to analyse the raw data gathered from the accelerometer. Obtained values were compared with pre-programmed activity categories, allowing software to assign the most appropriate activity category based on measured acceleration patterns.

Predefined activity categories of monitor are sleep, walk, play, eat, groom, jump, rest, drink, and litter. This project focuses on the last two.

Preprogrammed activities (activity monitor)	Observed activities (video analysis)
Drinking	Drinking
Eating	Eating
Littering	Urinating/Defecating

Table 2. Categories of activity registered in this project

Camera

This study strongly relied on on-going video recording. Because the room was supposed to be recorded 24/7, to decrease time spend on video footage analysis, decision was made to use motion sensor camera which simplified the process of detection of desired events.

The decided model was called AXIS M3086-V Dome Network Camera manufactured by Axis Communications AB. This product was marketed to provide great quality image in difficult light conditions (www.axis.com, n.d.).

Few important technical aspects of this camera were:

- Wide Dynamic Range (WDR) – technology that improves image quality in challenging light conditions, both bright and dim,
- 2.4mm lens – allows to capture a broader scene,
- F2.1 aperture – allows more light to enter the camera,
- Shutter speed 1/38500 s to 1/5 s – provides flexibility to adapt to various light conditions,
- 25/30 fps – common frame rate used in video recordings providing standard viewing.

The motion camera model features a deep learning processing unit (DLPU), which enables intelligent analytics for fast, efficient searches in both live and recorded videos. Moreover, with the preinstalled AXIS Object Analytics software, it is feasible to analyse video streams to detect and track specific objects or events of interest. This combination of advanced hardware and software ensures quick and accurate analysis of video data for a variety of purposes.

The camera was strategically positioned to cover the desired area, which included the drinking bowls and litter boxes. Its placement was optimized to capture the maximum part of the room and ensure comprehensive monitoring. Camera's intelligent programs used predefined scenarios to analyse the scene and determine when to trigger the camera based on the detection of specific events of interest.

Figure 3. Designed area of the experiment

Camera recorded materials directly on to memory card. At its peak almost 6000 recordings were created. To ensure a well-organized data gathering process, careful management and categorization of the recorded videos were crucial. Videos were analysed by observer and final 671 containing the events of drinking, eating, and littering were extracted. Full size of videos was 1.58 GB indicating a grand amount of data collected for this study.

Video analysis

The purpose of the video analysis was to determine whether the activity monitor's readings align with the activities captured in the videos in order to evaluate monitor's effectiveness and accuracy.

Approximately once a week camera was accessed by connecting it to a Dell Vostro 5502 laptop using an Ethernet cable. Network protocol IPv4 was used to locate camera's IP address and establish connection between camera and the laptop.

In AXIS portal all video recordings were listed. First stage of analysis included exclusion of videos that featured other cats in the room and not experimental unit, as well as videos completely unrelated to drinking, eating, and littering. Remaining videos were uploaded and saved in folders with the corresponding dates. Data on start, end, and duration of activities were entered manually to Microsoft® Excel document once a week.

Analysis of the video material was conducted before the access to raw data from activity monitor.

Protocol

The equipment setup for the experiment took place on April 18th, 2023, marking it the beginning of the study. The activity monitor base was provisioned through Wi-Fi to be activated. Monitor was securely attached to available collar and put on the cat. On the same day the motion sensor camera was set up and area of interest was designed. The camera operated continuously, recording 24 hours a day, 7 days a week, for a duration of 48 days. Experiment was concluded on June 5th, 2023, with disassembly of all the equipment involved in the study.

To ensure collection of all triggered videos a well-planned data collection was essential, that is why weekly visits to the cat shelter (site of experiment) were conducted in a weekly basis throughout the duration of this project. In total, 8 visits were made with the purpose of data gathering. The memory card in the camera had maximum capacity of thirty days' worth of storage. Any videos recorded beyond this period were overlapping of the videos captured at the beginning of the experiment.

Additionally, activity monitor was supposed to have enough battery life to run for 3 weeks. To avoid any setbacks, it was charged fully three times.

Until the 8th of May, which marked the twentieth day of the experiment, the video analysis primarily focused on two activities: urination and drinking. However, the analysis was quickly expanded to include elimination, as the activity monitor is, undoubtedly, unable to differentiate between actions during littering. Additionally, eating was included as an observed activity due to relatively low number of registrations for drinking alone as well as potential similarities in repetitive motions or movement patterns. Data analysis focused on data between 8th of May and 4th of June. Entries before 8th served as additional results or information.

The protocols were kept by observer, that is reviews of both video footage and raw data from the activity monitor throughout the entire duration of the experiment. Data were weekly entered manually to Microsoft® Excel document and recordings stored.

Data analysis

On three separate occasions the collar fell off from the cat. Those data were excluded from analysis due to error sources, as well as times during which the monitor was being charged. Entries for which the files were lost, were also excluded from analysis.

Since study took place in a cat shelter, apart from experimental unit other cats were present in the room. This made video analysis troublesome during eating, because during feeding, four to eight bowls were available for the group. It was established that if there were more than three seconds between eating, those entries would be kept as separate activities. It often took the individual less than three seconds to shift head to other bowl. If that contained more movement, like walking to other bowl, then since it is a different activity, it was kept separate.

Respective data were extracted from activity monitor and assembled with interpretation of cat's actions throughout experiment period as .json files[1].

Data from activity monitor that were representing time were timestamped in EPOCH seconds and needed conversation to human time. Before any analysis time synchronization of data was performed from UTC to CET time.

Microsoft Excel® files for both video analysis and data from activity monitor were stored by observer. Charts and tables based on the data were created in the same program. The character of the data set allowed for the application of descriptive statistics alone. No statistical analyses or modeling were conducted due lack of sufficient data. The descriptive statistics served to provide a comprehensive overview of the key findings and summarize results in a clear manner without the need for complex analysis.

---

[1] Iñigo Javier Puente Henales Phronesis Technologies Lab Limited via Moggie AB, 2023-06-27

4. Results

At the end of the study, 5989 recordings were registered by motion sensor camera. Total duration of the video recordings with activities of interest amounted to 18 hours, 40 minutes, and 16 seconds. From those recordings, specific activities were timestamped and analysed, resulting in a summary of 10 hours, 13 minutes, and 52 seconds.

A compilation of all registrations for observed and registered activities during the study period was made in Table 3. Length of video data approved to analysis was 9 hours 48 minutes and 50 seconds with:

- 30 minutes and 39 seconds of littering,
- 1 hour 15 minutes and 7 seconds of drinking,
- 8 hours, 3 minutes and 4 seconds of eating.

Monitor recorded 13 hours 50 minutes and 34 seconds of categorised activities.

	Activity monitor	**Motion sensor camera**
Litter	15	65
Drink	6	90
Eat	32	363
TOTAL	**53**	**518**

Table 3. Amount of specific activity registered by activity monitor and motion sensor camera

In aggregated database from activity monitor, there was a column representing number of 2.4 second intervals when specific activity was identified. However, for all registrations of DRINK and LITTER, no time intervals were recorded, only that activity was identified.

Results from activity monitor are limited compared to "gold standard" of video analysis. DRINK and LITTER were some of the most underrepresented activities in original training dataset for activity monitor[2]. There was no corresponding registration for activity monitor and motion sensor camera.

To further investigate lack of correlation, scatter plots were made for drinking (Figure 4) and littering registrations (Figure 5). Those were created to visualise distribution of entries in both activities from activity monitor and motion sensor camera. In some instances, registrations from the activity monitor and the camera occurred in proximity, suggesting some degree of agreement between the two techniques.

[2] Iñigo Javier Puente Henales Phronesis Technologies Lab Limited via Moggie AB, 2023-06-27

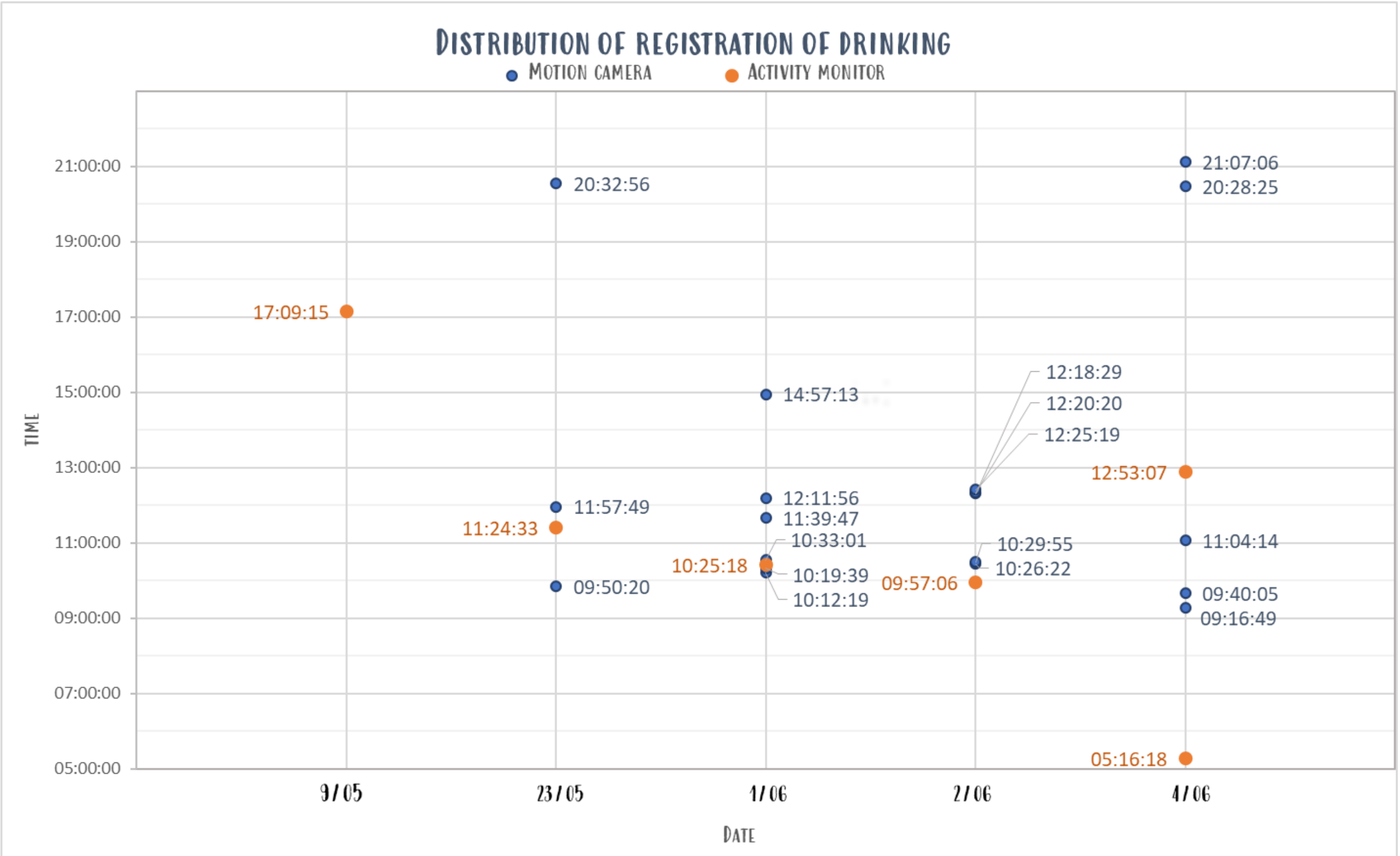

Figure 4. Distribution of registrations of drinking

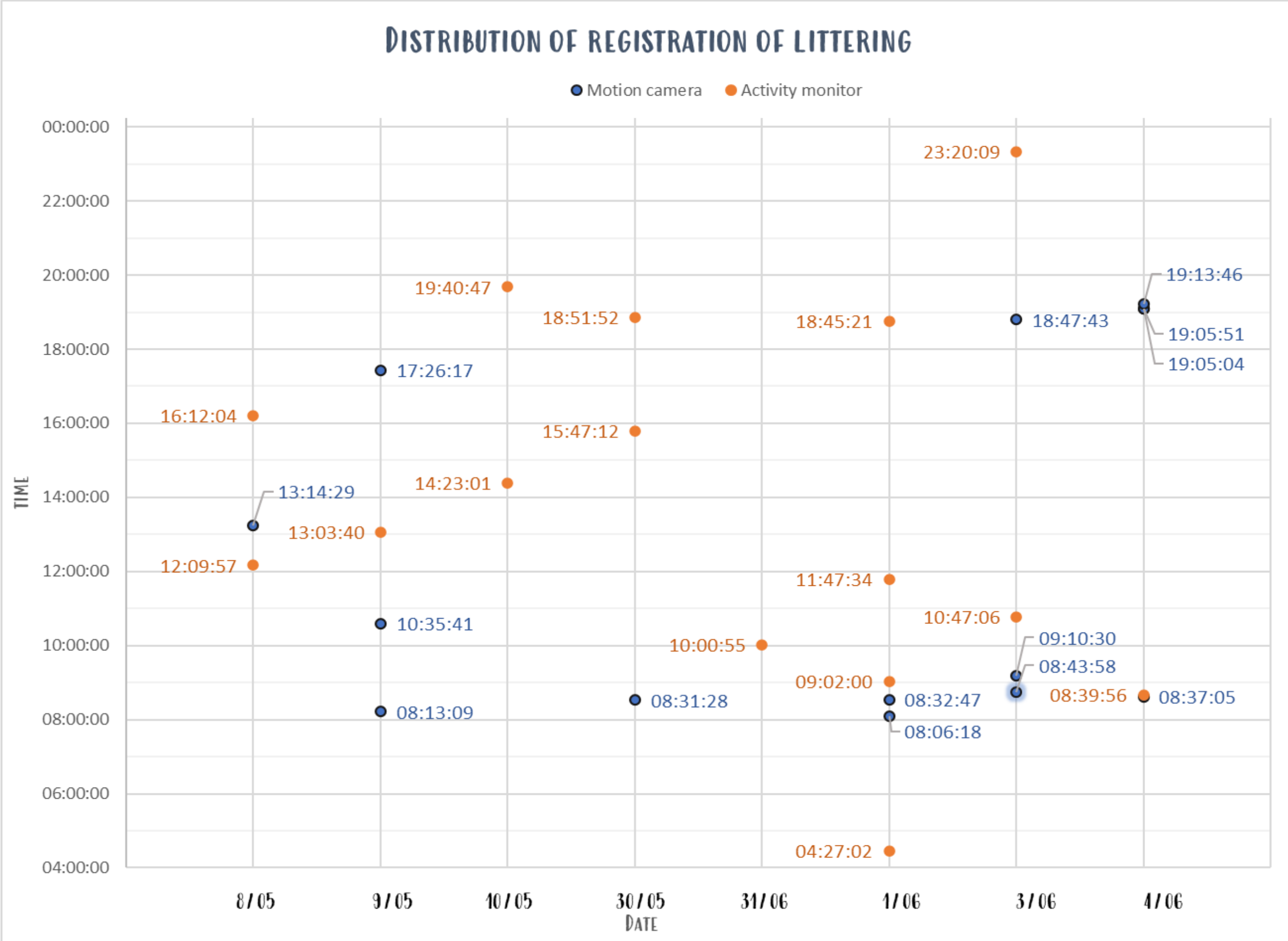

Figure 5. Distribution of registrations of littering

However, a significant number of incompatibilities were present as well. Most of the entries were observed by just one monitoring method and never detected by the other. With motion sensor camera being established as the gold standard for activity monitoring, it becomes clear that the activity monitor displays deviations requiring further investigation and refinement to increase the accuracy of algorithmic registration.

An unplanned but interesting event was observed during the experiment. On the 18th of May, that is tenth day of the official study, the diet of cats in the shelter room was changed. Number of portions was decreased from three to two, and brand of feed was changed. To present a significant increase in registrations of drinking after the change of feeding routine, entries before official start of the study (from 18/04/2023 to 7/05/2023) were included in the making of Figure 6. Until the day of diet change experimental unit on average consumed water approximately 0.5 times per day, with 0 being the most frequent number of drinking per day. After diet change, the average number of drinking activity was 4.5, and 6 being the most frequent number of visits to water bowl in a day. Figure 7 was created to illustrate dynamics of activities after change in the diet. It shows patterns of drinking, eating, and littering activities for a duration of what was established as official study.

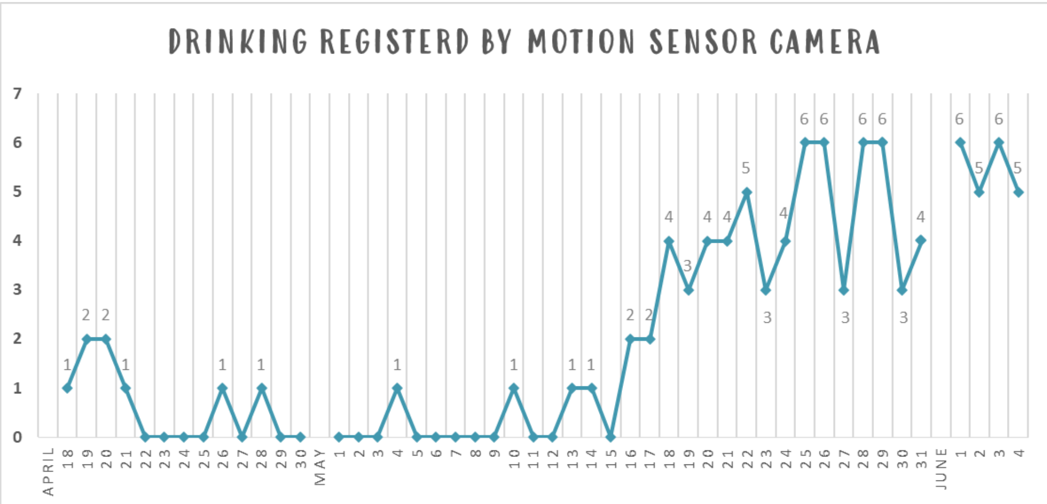

Figure 6. Drinking registered by motion sensor camera

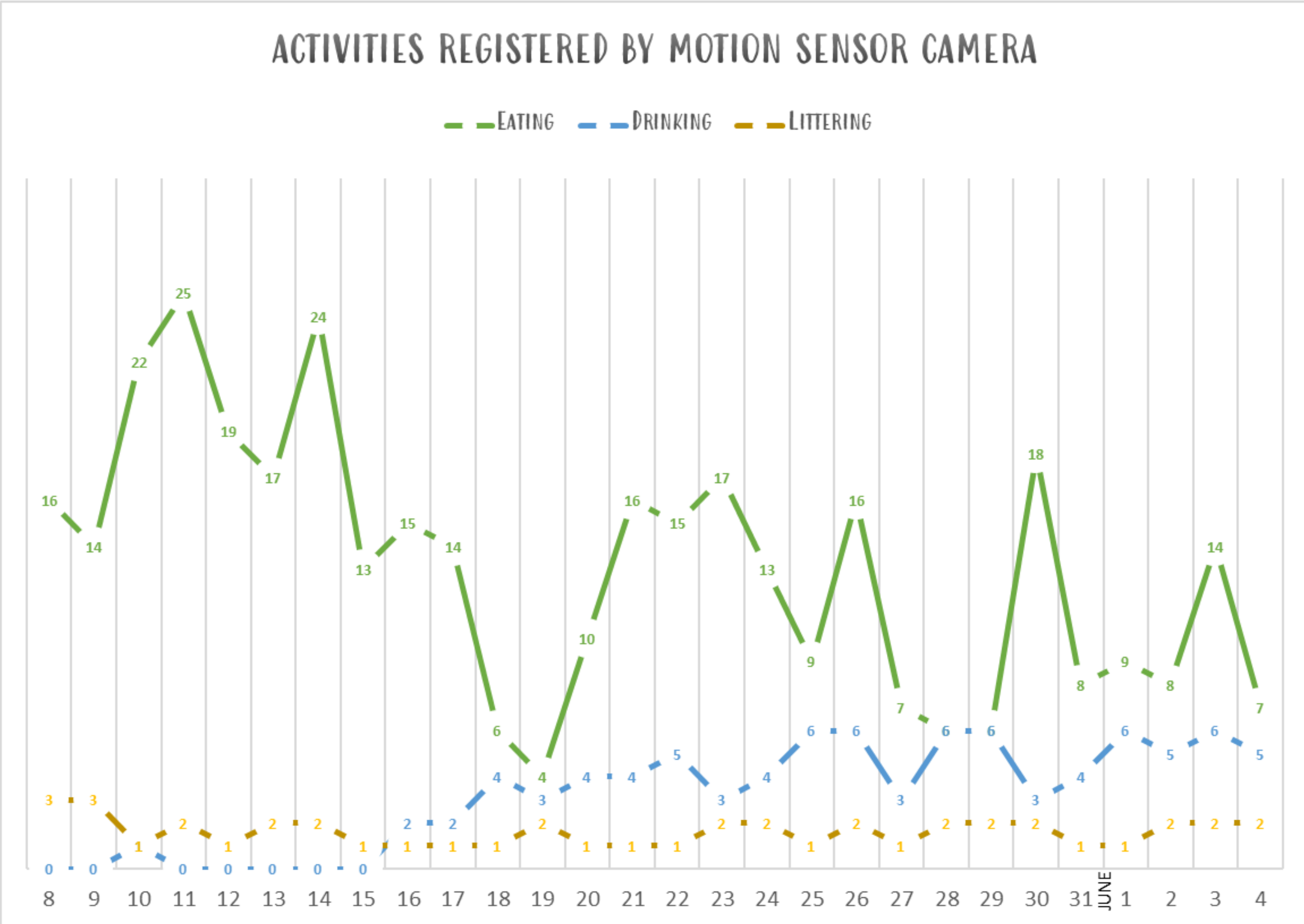

Figure 7. Activities registered by motion sensor camera (from 18/05/2023 to 4/06/2023)

The predefined category LITTER is used to register the usage of the litter box. However, if results concern specific physiological function, then further verification is necessary. Upon closely observed usage of litter box, it was found that 69% of the registered activities corresponded to urination, while the remaining 31% were related to elimination.

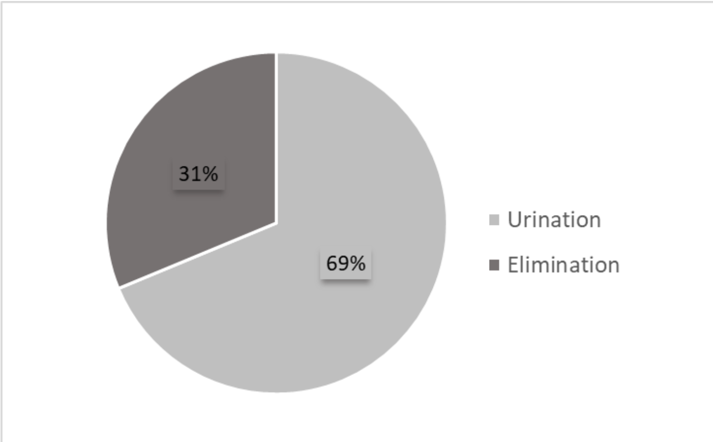

Figure 8. Littering observed in video recordings

5. Discussion

5.1 Discussion on results

The results of this study revealed an unexpected finding – a complete absence of correlation between the data obtained from activity monitor and the motion sensor camera. Based on the results obtained, the null hypothesis that there is no correlation between the activities registered by the activity monitor and the corresponding videos was supported. The analysis revealed no significant relationship or association between the recorded activities from the activity monitor and the activities captured in the videos.

Activity monitor did not register drinking and littering activities as well as the camera did. It highlights the need for further investigation into the underlying causes of distinction between activity monitor and actions observed on video. It is important to identify the factors that may have contributed to the lack of agreement between these two sources of data.

One of the goals of this particular project was also to create a base of video materials of feline behaviour that would be used to further improve the algorithms by the collar company. While this work regards two specific activities, recordings include some additional categories as well. This video dataset with corresponding annotations could serve as quality resource for training machine learning algorithms. It would allow to better interpret raw accelerometer data resulting in more accurate activity predictions. Additionally, it could be used as a 'demo' platform with stimulated environment for algorithm testing before real-world deployment.

The company was aware of the weaknesses of the algorithm and put in efforts to improve it, such as initiating this study. Advancing algorithms is crucial for the accuracy and efficiency of the product.

Results found in Devlin and Olausson (2018) study, presented alignment between activity monitor and video analysis of 66.39% for Katt 1 and 89.05% for Katt 2 for five different activities – rest, walk, play, play on the back and force.

Those results were higher than those established in Arvidsson and Spence (2018) which showed a general agreement, between observed and recorded activity of 68.4% for Katt 1 and 66.8% for Katt 2 for rest, walk, play, play on the back and force. Additionally, this research incorporated eating and drinking as one category for video analysis, with Katt 1 dedicating 11.5% of recorded time to eating and drinking, and Katt 2 – 7%. However, there were no records on drinking as a separate activity. For elimination activities, neither the activity monitor nor the camera registered anything for 3 hours 6 minutes 22 seconds of total recorded time for both cats. This category was put into the study just as authors’ suggestion for important topic and area in future research.

In Mathiasson (2019) an overall positive predictive value of 66.0% was demonstrated between activity monitor registrations via mobile app and the observer's registrations based on video footage for predefined activities – walk, run, play, eat, drink, litter, groom, jump, rest and sleep. Drink and litter had no corresponding video records to confirm their occurrence and were not calculated in the analysis. Average positive predictive value between the observer's recordings based on video footage and the activity collar's recordings for eating was 61.72% for 4 out of 6 cats that ate, with correlation coefficient value of 0.72.

While student theses conducted previously at The Swedish University of Agricultural Sciences used similar tool, the details and specific objectives differ from current study. None of those studies analysed drinking separately or registered elimination actions. The previous theses can be seen as foundation for validation of activity monitors in cats, whereas the focus of present study was to investigate specific activities and their application to certain scenario. By narrowing the scope and targeting particular behaviors this study contributes to the broader understanding and application of activity monitors in feline health and disease management. The findings of the previous theses provide valuable, informative insights and support for the use of activity monitors, present study builds upon this basis by exploring the practical implementation and validation in a more specific manner.

It is suspected that drinking and littering activities are more complex than predefined categories studies in mentioned theses. Because those occur much less frequent, it might be more difficult to establish quality algorithm to correctly register and analyse DRINK and LITTER. This opens avenues for further research and refinement of existing models and methodologies. While these activities have not been the primary focus for the company, recent efforts have been made to address these difficulties. As part of its commitment to product improvement, the company is making efforts to increase the accuracy of algorithmic registration and analysis of DRINK and LITTER activities.

There is a limited amount of research specifically focused on the validation of drinking and littering behavior in cats using activity monitors. To author's knowledge, no studies have been conducted specifically in this context.

Nonetheless, the study conducted by Watanabe et al. (2005) recorded a high level of accuracy (100%) in registering drinking behaviors with the activity monitor. The research included a broad range of activities, including groom by licking, hind claw, and forepaw; eat cat food and half-dried fish; drink water; travel by walk trot and gallop. From 113 minutes of video footage recorded, the study revealed mean duration of drinking episodes at 45.6 ± 22.6 seconds, taking 3.4% of the total captured footage. The activity monitor effectively registered instances of drinking with a high degree of accuracy.

It is worth highlighting the findings of studies in different animal species that have shown more promising results. A pilot study by Williams et al. (2019) analysed drinking behaviour in beef cattle using a neck-mounted triaxial accelerometer. The results established that drinking behavior could be categorised from standing (head up) with 100% accuracy. While this study focused on a different species, it provides insights into the potential capabilities of accelerometers for monitoring drinking behavior. Although the present study did not meet desired correlation, it serves as a valuable contribution to the limited research on this topic in cats.

The presence of a predefined category labeled "LITTER" raises concerns about accurately interpreting which specific physiological action was registered. LITTER contains two physiological actions – urine elimination and defecation. Without a method for counterchecking, e.g., video capture, there is no possibility to differentiate which specific action was registered as LITTER by activity monitor.

Various methods for monitoring littering were presented, which are not typically challenging in a household with a single cat. However, in the context of this study, where one individual cat cohabited with 2 to 4 other cats. It is important to highlight the potential difficulty associated with monitoring littering accurately, without verifying which individual performed particular physiological action.

This difficulty increases when considering diabetic cats, where monitoring urine output holds significance. It crucial to emphasize that registration from activity monitor alone would not be enough to control urine output in diabetic cat, and as mentioned before it should be supplemented with additional methods. Referring to recorded data, registrations captured by activity monitor, video observations from those days captured 21 activities considered as LITTER that included roughly 76% of elimination and 24% of defecations actions. Moreover, the presence of more cats in a household makes accurate monitoring becomes notably complicated due to the need to not only verify the precise physiological activity that was carried out by the diabetic cat but also to determine the particular litter box used among several cats, the procedure of correct monitoring.

This study was conducted in a cat shelter and apart from experimental unit other cats were present in the room. This made video analysis troublesome particularly during eating. In such scenario, multiple cats had access to four to eight bowls. Often cats would switch from one bowl to another and continue eating. This happened several times during each meal. It is important to mind the dynamic of environment and interactions between animals to suit the study. Because video analysis became challenging due to risk of overlapping activities, to address this a specific criterion was established. Entries were considered as separate activities if the pause between feeding was longer that three seconds and annotated as two instances of eating. It often took the individual less than three seconds to shift head to other bowl. However, if the shift contained more movement, like walking to other bowl, then since it was classified as different activity it was kept separate.

The concurrent observations in this study revealed that change in feeding repertoire had an impact on drinking behavior in cats. When on dry food diet cats drink tend to more water to compensate for lack of dietary moisture when eating wet food (Zanghi, 2017; 2018). The cat's dependency on drinking water tends to decrease with wet or raw meals, which generally include over 75% moisture (Buckley et al., 2011).

Video recordings were analysed from April 18th to May 8th to capture all drinking activities captured in the duration of this experiment. Prior to the diet change only 14 drinking activities were recorded. However, after the diet change, an additional 85 drinking activities were observed, giving the total of 99 drinking activities throughout the entire experiment. This indicates a significant increase in drinking behavior following the feeding alteration. Specifically, the change in diet led to a 507.14% increase in drinking activities. This finding confirms that cats on mostly dry food diet may increase their voluntary drinking by nearly six times, although their overall water intake may still be 30% less compared to cats on wet or raw diet (Buckley et al., 2011). These results demonstrate the influence of diet on drinking behavior and emphasize the importance of considering dietary factors when assessing and monitoring water intake in cats.

5.2 Potential of use

Despite underwhelming results of this experiment, potential of activity monitors is undeniable. Activity monitors have vast potential, ranging from analysing behavior and monitoring physical activity levels to assessing animal welfare and managing various health disorders. A closer examination of the references used in this study reveals a variety of studies on benefits of activity monitors across different fields. Potential applications of activity monitors have also been increased by the developing technological improvements, such as better data gathering techniques, higher precision, and the integration of more sensors (Brown, 2013).

While the results obtained from a single animal provide valuable insights and serve as a pilot study, it is important to acknowledge that despite the limited sample size, findings can still contribute to the broader understanding of feline drinking and littering behaviors. Future studies could use these results to provide a more comprehensive understanding in larger sample size of cats.

Currently, veterinarians heavily rely on subjective measurements obtained through questionnaires and medical interviews with owners (Brown et al., 2010; Karas et al., 2019). However, this approach can be limited by owners' availability, particularly if they work full time and are unable to observe their pets during the day (Belda et al., 2018). This may result in potential oversight of important signs of failed health. Activity collars provide a remote solution and allows longer and continuous data collection, promising for improving monitoring of pets in a home setting. This is especially advantageous for monitoring activities that occur rarely, such as drinking. In addition, it is extremely important to recognize the usefulness of activity monitors for pet owners, that are recently more demanding of higher standards of reliable tools to assess wellbeing of their animals (Chapa et al., 2020). The app developed by collar manufacturer has a user-friendly design, is easy to use, and does not require advanced veterinary knowledge to follow a pet's health status. Acquiring data from an activity monitor via a mobile phone is not only quick and convenient but also simplifies accessing important information and real-time analytics available without the need for complicated calculations (Zhou and Hu, 2008). Previous data are stored which allows tracking and monitoring activity trends over time.

While this experiment focused on analysis of drinking and littering for the control of diabetes, obtained registrations can have potential applications in other disorders as well, such as kidney disease and urinary tract infections. By continuously monitoring drinking, activity monitors can provide valuable information on fluid intake and deviations from normal drinking patterns or irregular littering can serve as early warning signs of problems in the urinary system. Furthermore, changes in frequency of drinking, eating, urination, defecation are behavioural indicators of stress in cats (Bradshaw, 2012).

Cats have a low desire to drink (Buckley et al., 2011) and there is no definition of adequate water intake to recommend (Zanghi, 2017). Additionally fluid consumption is highly depended on various factors, such as age, activity levels, diet, and is a very individual concept. With broad analysis of cat's drinking habits, this study commits to understanding aspects of feline hydration, individual variability, and the factors that influence their drinking behavior. In a future this could contribute to the development of guidelines that promote optimal hydration practices for cats.

Integrating motion sensory camera in longer experiments offers many benefits to the evenness of work and efficiency of data analysis process. This eliminates the need to manually analyse video material of complete day-by-day recordings (Karas, 2019). Drinking and littering occur relatively infrequently throughout the day, thus searching for them in a lengthy file would prolong finalization of research. That decreases the workload needed to prepare videos for further analysis and allows to focus the efforts specifically on the area of interest. Additionally, it eliminates the need for costly serves, network capacity demands and minimize storage (www.axis.com, n.d.).

5.3 Limitations and room for improvement

One of the main limitations of this study was the lack of results that would allow for broader and deeper data analysis and validation of the activity monitor. Specifically, the absence of significant correlations between data from activity monitor and motion sensor camera limits the extent to which conclusions can be drawn. This makes it difficult to determine the reliability and validity of activity monitor in identifying and quantifying the desired activities.

It is crucial to recognize the need for further research and improvement to strengthen the validity and value of activity monitors in similar studies. The challenges arise when capturing and analysing infrequent behaviors, such as drinking and littering. Developing competent algorithms for accelerometer-based monitoring is therefore complex and demands advanced analytical tools to accurately detect and quantify various activities. Currently, video recording serves as the gold standard in animal activity monitoring. The absence of a strong correlation in results could be attributed to the underdeveloped algorithm, which limits the ability of activity monitor to accurately identify and interpret specific activities, especially those that occur less frequently. The potential of activity monitors is promising, however there is a need for algorithmic advancement to refine and develop this technology.

Additionally, this could indicate the potential value in exploring alternative technologies, such as advanced sensors offering objective measurements of time spent at specific locations, in this study close proximity of bowls and littering box.

There isn't yet a commonly used standardized method to measure physical activity with wearable accelerometers (Karas et al., 2019). Moreover, the interpretation of accelerometer data is highly influenced by individual variations and characteristics. This emphasizes the need for further research to establish standardized methods and develop criteria for interpreting and comparing accelerometer data. In the context of this experiment, which focused on one cat, it is essential to acknowledge that obtained results may not be fully representative in a larger population. Given that drinking and littering are very individual traits, this is particularly significant. While the results of this study offer valuable insight, future studies with larger sample sizes are necessary to obtain more comprehensive and generalized data.

Devices that are attached to a collar are movable and not fixed to the body. This may result in inaccurate acceleration readings, which would reduce the accuracy of the body movement measurements (Dickinson et al., 2020). Additionally, the fact that some cat’s simply do not tolerate collars is important drawback to use such a tool. Alternative methods or strategies may need to be explored for monitoring the activity levels and behaviors of cats that do not tolerate collars.

Compared to other predefined categories of activity drinking and littering occurs undoubtably least often. To obtain significant results the experiment should be run for a longer period. To minimise workload for a video analysis this study used motion sensor camera. However, some limitations came along. Firstly, due to positioning of the camera, sometimes it was difficult to interpret start and end of activity. The cat approaching water bowl did not equal to start of drinking, especially since the individual used in this experiment often took longer to start drinking. In some cases, a camera with horizontal level of recording would be appreciated, because there was no possibility to countercheck if activity started. Secondly, because motion sensor camera is triggered by movement in designed area, as a result sometimes recording stopped if there was no pronounced motion, yet experimental unit was still in a frame using feeding bowl. In a few instances recording was cut short but those were counted as errors and deleted.

One limitation of the study was related to the design of the AXIS software used for recording, specifically the lack of a "mass download" option, which would made the process of saving all recorded materials time-consuming. As a result, the observer had to selectively store only the recordings with activities of interest, which limited the availability of additional materials for potential future use and analysis. Additionally, depending on the size of the memory card and the file sizes themselves, there were limitations on the number of materials that could be registered. Another troublesome aspect in this study, was the overlapping of stored videos after 30 days, posing a risk of losing important materials.

The battery life of 3 to 4 weeks can be considered a potential practical limitation worth mentioning (Chapa et al., 2020). While it may not significantly impact the overall findings or validity of the study, it is important to acknowledge that one must remember to charge the device regularly. Failure to do so could result in data loss if the monitor turns off due to an empty battery.

6. Conclusions

This study was conducted with the general aim to validate the registrations of an activity monitor designed for cats, specifically its effectiveness in detecting drinking and littering activities. The results revealed that there was no correlation between the data obtained from the activity monitor and the video observations from the motion sensor camera.

These findings support the null hypothesis, which expected that there is no significant correlation between the activities registered by the activity monitor and the corresponding videos. While these results may be considered negative, they offer valuable information on activity monitoring and potential for early detection of health conditions in felines.

The results of this study contribute to the limited research on the validation of drinking and littering behavior in cats using activity monitors. It emphasizes the complexity of accurately registering and monitoring these activities. While the results may be specific to the individual cat in this study, they provide valuable insights and serve as a pilot study for future research in this area. The limitations and challenges encountered in this study underline the need for further refinement and improvement in this technology, but acknowledge the valuable insights activity monitors provide and their role in future research.

Negative validation results imply that the activity monitor might not effectively register relevant behaviors or physiological changes linked to diabetes. However, despite underwhelming findings it should not rule out all potential applications in monitoring feline behaviors and managing health disorders remain promising. Activity monitors still hold the potential to support the management of feline diabetes and monitor key activities associated with this disorder, especially due to the advantage of remote capabilities. By providing objective data on physical activity levels, they could support control of effectiveness of treatment plans, and promote overall health and well-being in diabetic cats.

Until further development and refinement, using activity monitor to control drinking and littering may need reconsideration due to lack of correlation with observation, however, there remains optimism that advancements and improvements could lead to more effective equipment in the future.

7. Reference list

American Diabetes Association (2013). Diagnosis and Classification of Diabetes Mellitus. *Diabetes Care*, [online] 37(Supplement_1), pp.S81–S90. doi:https://doi.org/10.2337/dc14-s081.

Andrews, C.J., Potter, M.A. and Thomas, D.G. (2015). Quantification of activity in domestic cats (Felis catus) by accelerometry. *Applied Animal Behaviour Science*, 173, pp.17–21. doi:https://doi.org/10.1016/j.applanim.2015.05.006.

Andrews, C.J., Potter, M.A., Yapura, J. and Thomas, D.G. (2022). Accelerometry and infrared thermography show potential for assessing ovarian activity in domestic cats (Felis catus). *Theriogenology*, 179, pp.237–244. doi:https://doi.org/10.1016/j.theriogenology.2021.12.005.

Arvidsson, M. & Spence, A.C. (2018). Aktivitetsmonitor på katt en pilotstudie av överensstämmelsen mellan registrerad och observerad aktivitet med fokus på skillnad mellan katter av olika storlek. Bachelor thesis, Swedish University of Agricultural Sciences, Uppsala, Sweden. https://stud.epsilon.slu.se/13972/

Aspinall, V. (2012). *Complete textbook of veterinary nursing*. Edinburgh: Saunders Elsevier.

Barwick, J., Lamb, D., Dobos, R., Schneider, D., Welch, M. and Trotter, M. (2018a). Predicting Lameness in Sheep Activity Using Tri-Axial Acceleration Signals. *Animals*, 8(1), p.12. doi:https://doi.org/10.3390/ani8010012.

Barwick, J., Lamb, D.W., Dobos, R., Welch, M., Schneider, D. and Trotter, M. (2020). Identifying Sheep Activity from Tri-Axial Acceleration Signals Using a Moving Window Classification Model. *Remote Sensing*, 12(4), p.646. doi:https://doi.org/10.3390/rs12040646.

Barwick, J., Lamb, D.W., Dobos, R., Welch, M. and Trotter, M. (2018b). Categorising sheep activity using a tri-axial accelerometer. *Computers and Electronics in Agriculture*, 145, pp.289–297. doi:https://doi.org/10.1016/j.compag.2018.01.007.

Belda, B., Enomoto, M., Case, B.C. and Lascelles, B.D.X. (2018). Initial evaluation of PetPace activity monitor. *The Veterinary Journal*, 237, pp.63–68. doi:https://doi.org/10.1016/j.tvjl.2018.05.011.

Bradshaw, J.W.S., Casey, R.A. and Brown, S.L. (2013). *The behaviour of the domestic cat*. Wallingford: Cabi.

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), pp.66–70. doi:https://doi.org/10.2460/javma.237.1.66.

Brown, D.D., Kays, R., Wikelski, M., Wilson, R. and Klimley, A. (2013). Observing the unwatchable through acceleration logging of animal behavior. *Animal Biotelemetry*, 1(1), p.20. doi:https://doi.org/10.1186/2050-3385-1-20.

Buckley, C.M.F., Hawthorne, A., Colyer, A. and Stevenson, A.E. (2011). Effect of dietary water intake on urinary output, specific gravity and relative supersaturation for calcium oxalate and struvite in the cat. *British Journal of Nutrition*, 106(S1), pp.S128–S130. doi:https://doi.org/10.1017/s0007114511001875.

Cannon, M. and Forster-Van Hijfte, M. (2006). *Feline medicine : a practical guide for veterinary nurses and technicians*. Edinburgh ; New York: Elsevier Butterworth Heinemann.

Chapa, J.M., Maschat, K., Iwersen, M., Baumgartner, J. and Drillich, M. (2020). Accelerometer systems as tools for health and welfare assessment in cattle and pigs – A review. *Behavioural Processes*, 181, p.104262. doi:https://doi.org/10.1016/j.beproc.2020.104262.

Cook, D.J., Thompson, J.E., Prinsen, S.K., Dearani, J.A. and Deschamps, C. (2013). Functional Recovery in the Elderly After Major Surgery: Assessment of

Mobility Recovery Using Wireless Technology. *The Annals of Thoracic Surgery*, [online] 96(3), pp.1057–1061. doi:https://doi.org/10.1016/j.athoracsur.2013.05.092.

Cooper, B., Turner, L. and Mullineaux, E. (2020). *The BSAVA Textbook of Veterinary Nursing*. 6th ed. Gloucester England: British Small Animal Veterinary Association.

Cornell Feline Health Center (2018). *Feline Diabetes*. [online] Cornell University College of Veterinary Medicine. Available at: https://www.vet.cornell.edu/departments-centers-and-institutes/cornell-feline-health-center/health-information/feline-health-topics/feline-diabetes.

Coughlin, C.E. and van Heezik, Y. (2014). Weighed down by science: do collar-mounted devices affect domestic cat behaviour and movement? *Wildlife Research*, [online] 41(7), p.606. doi:https://doi.org/10.1071/wr14160.

Culp, W.T.N., Mayhew, P.D. and Brown, D.C. (2009). The Effect of Laparoscopic Versus Open Ovariectomy on Postsurgical Activity in Small Dogs. Veterinary Surgery, [online] 38(7), pp.811–817. doi:https://doi.org/10.1111/j.1532-950x.2009.00572.x.

den Uijl, I., Gómez Álvarez, C.B., Bartram, D., Dror, Y., Holland, R. and Cook, A. (2017). External validation of a collar-mounted triaxial accelerometer for second-by-second monitoring of eight behavioural states in dogs. *PLOS ONE*, 12(11), p.e0188481. doi:https://doi.org/10.1371/journal.pone.0188481.

Devlin, N. & Olausson, S. (2018). Aktivitetshalsband en pilotstudie för att utvärdera tillförlitligheten i ett halsbands mätningar av katters aktivitet. Bachelor thesis, Swedish University of Agricultural Sciences, Uppsala, Sweden. https://stud.epsilon.slu.se/13971/

Dickinson, E.R., Stephens, P.A., Marks, N.J., Wilson, R.P. and Scantlebury, D.M. (2020). Best practice for collar deployment of tri-axial accelerometers on a terrestrial quadruped to provide accurate measurement of body acceleration. *Animal Biotelemetry*, 8(1). doi:https://doi.org/10.1186/s40317-020-00198-9

Dulaney, D.R., Hopfensperger, M., Malinowski, R., Hauptman, J. and Kruger, J.M. (2017). Quantification of Urine Elimination Behaviors in Cats with a Video Recording System. *Journal of Veterinary Internal Medicine*, 31(2), pp.486–491. doi:https://doi.org/10.1111/jvim.14680.

Hansen, B.D., Lascelles, B.D.X., Keene, B.W., Adams, A.K. and Thomson, A.E. (2007). Evaluation of an accelerometer for at-home monitoring of spontaneous activity in dogs. *American Journal of Veterinary Research*, 68(5), pp.468–475. doi:https://doi.org/10.2460/ajvr.68.5.468.

Jones, S., Dowling-Guyer, S., Patronek, G.J., Marder, A.R., Segurson D'Arpino, S. and McCobb, E. (2014). Use of Accelerometers to Measure Stress Levels in Shelter Dogs. *Journal of Applied Animal Welfare Science*, 17(1), pp.18–28. doi:https://doi.org/10.1080/10888705.2014.856241.

Kang, M.-H., Kim, D.-H., Jeong, I.-S., Choi, G.-C. and Park, H.-M. (2015). Evaluation of four portable blood glucose meters in diabetic and non-diabetic dogs and cats. *Veterinary Quarterly*, 36(1), pp.2–9. doi:https://doi.org/10.1080/01652176.2015.1092617.

Karas, M., Bai, J., Strączkiewicz, M., Harezlak, J., Glynn, N.W., Harris, T., Zipunnikov, V., Crainiceanu, C. and Urbanek, J.K. (2019). Accelerometry data in health research: challenges and opportunities. *Statistics in biosciences*, [online] 11(2), pp.210–237. doi:https://doi.org/10.1007/s12561-018-9227-2.

Kooros, S. (2021). *Accelerometers give us a glimpse into the hidden lives of wildlife*. [online] www.wildlifetek.com. Available at: https://www.wildlifetek.com/blog/accelerometers.

Lascelles, B.D.X., Hansen, B.D., Roe, S., DePuy, V., Thomson, A., Pierce, C.C., Smith, E.S. and Rowinski, E. (2007). Evaluation of Client-Specific Outcome Measures and Activity Monitoring to Measure Pain Relief in Cats with Osteoarthritis. *Journal of Veterinary Internal Medicine*, 21(3), pp.410–416. doi:https://doi.org/10.1111/j.1939-1676.2007.tb02983.x.

Lascelles, B.D.X., Hansen, B.D., Thomson, A., Pierce, C.C., Boland, E. and Smith, E.S. (2008). Evaluation of a digitally integrated accelerometer-based activity monitor for the measurement of activity in cats. *Veterinary Anaesthesia and Analgesia*, 35(2), pp.173–183. doi:https://doi.org/10.1111/j.1467-2995.2007.00367.x.

Mathiasson K. (2021) Aktivitetshalsband på katt – verifiering av tillförlitligheten i mätningar av katters fysiska aktivitet. Master's thesis, Swedish University of Agricultural Sciences, Uppsala, Sweden. https://stud.epsilon.slu.se/16658/

Mitchell, S.C. (2023). *Why Is My Cat Drinking a Lot of Water?* [online] www.petmd.com. Available at: https://www.petmd.com/cat/symptoms/why-my-cat-drinking-lot-water.

Moggie.me. (2023). *Master Your Cat's Health with Moggie's Daily Activity Tracker*. [online] Available at: https://moggie.me/blog/how-to-encourage-my-cat-to-drink [Accessed 4 Jun. 2023].

Rand, J.S., Fleeman, L.M., Farrow, H.A., Appleton, D.J. and Lederer, R. (2004). Canine and Feline Diabetes Mellitus: Nature or Nurture? *The Journal of Nutrition*, [online] 134(8), pp.2072S2080S. doi:https://doi.org/10.1093/jn/134.8.2072s.

Ray, M., Carney, H.C., Boynton, B., Quimby, J., Robertson, S., St Denis, K., Tuzio, H. and Wright, B. (2021). 2021 AAFP Feline Senior Care Guidelines. *Journal of Feline Medicine and Surgery*, 23(7), pp.613–638. doi:https://doi.org/10.1177/1098612x211021538.

Reusch, C.E. (2015). Feline Diabetes Mellitus. *Canine and Feline Endocrinology*, pp.258–314. doi:https://doi.org/10.1016/b978-1-4557-4456-5.00007-9.

Reusch, C.E., Kley, S. and Casella, M. (2006). Home monitoring of the diabetic cat. *Journal of Feline Medicine and Surgery*, 8(2), pp.119–127. doi:https://doi.org/10.1016/j.jfms.2005.09.003.

Ringgenberg, N., Bergeron, R. and Devillers, N. (2010). Validation of accelerometers to automatically record sow postures and stepping behaviour. *Applied Animal Behaviour Science*, 128(1-4), pp.37–44. doi:https://doi.org/10.1016/j.applanim.2010.09.018.

Robbins, M.T., Cline, M.G., Bartges, J.W., Felty, E., Saker, K.E., Bastian, R. and Witzel, A.L. (2018). Quantified water intake in laboratory cats from still, free-falling and circulating water bowls, and its effects on selected urinary parameters. *Journal of Feline Medicine and Surgery*, 21(8), pp.682–690. doi:https://doi.org/10.1177/1098612x18803753.

Robert, B., White, B., Renter, D.G. and Larson, R.L. (2009). Evaluation of three-dimensional accelerometers to monitor and classify behavior patterns in cattle. *Computers and Electronics in Agriculture*, 67(1-2), pp.80–84. doi:https://doi.org/10.1016/j.compag.2009.03.002.

Slingerland, L.I., Fazilova, V.V., Plantinga, E.A., Kooistra, H.S. and Beynen, A.C. (2009). Indoor confinement and physical inactivity rather than the proportion of dry food are risk factors in the development of feline type 2 diabetes mellitus. *The Veterinary Journal*, 179(2), pp.247–253. doi:https://doi.org/10.1016/j.tvjl.2007.08.035.

Sparkes, A.H., Cannon, M., Church, D., Fleeman, L., Harvey, A., Hoenig, M., Peterson, M.E., Reusch, C.E., Taylor, S. and Rosenberg, D. (2015). ISFM Consensus Guidelines on the Practical Management of Diabetes Mellitus in Cats. *Journal of Feline Medicine and Surgery*, 17(3), pp.235–250. doi:https://doi.org/10.1177/1098612x15571880.

Stadig, S., Lascelles, B.D.X. and Bergh, A. (2016). Do cats with a cranial cruciate ligament injury and osteoarthritis demonstrate a different gait pattern and behaviour compared to sound cats? *Acta Veterinaria Scandinavica*, 58(S1). doi:https://doi.org/10.1186/s13028-016-0248-x.

Watanabe, S., Izawa, M., Kato, A., Ropert-Coudert, Y. and Naito, Y. (2005). A new technique for monitoring the detailed behaviour of terrestrial animals: A case study with the domestic cat. *Applied Animal Behaviour Science*, 94(1-2), pp.117–131. doi:https://doi.org/10.1016/j.applanim.2005.01.010.

Williams, L.R., Bishop-Hurley, G.J., Anderson, A.E. and Swain, D.L. (2019). Application of accelerometers to record drinking behaviour of beef cattle. *Animal Production Science*, 59(1), p.122. doi:https://doi.org/10.1071/an17052.

Wolff-Hughes, D.L., Bassett, D.R. and White, T. (2018). In response to: Re-evaluating the effect of age on physical activity over the lifespan. *Preventive Medicine*, 106(101), pp.231–232. doi:https://doi.org/10.1016/j.ypmed.2017.09.003.

www.axis.com. (n.d.). *AXIS M3086-V Dome Camera | Axis Communications*. [online] Available at: https://www.axis.com/products/axis-m3086-v [Accessed 5 Jul. 2023].

Yamazaki, A., Kazuya Edamura, Koji Tanegashima, Yuma Tomo, Yamamoto, M., Hirao, H., Seki, M. and Asano, K. (2020). Utility of a novel activity monitor assessing physical activities and sleep quality in cats. *PLoS ONE*, 15(7), pp.e0236795–e0236795. doi:https://doi.org/10.1371/journal.pone.0236795.

Zanghi, B.M., Gerheart, L. and Gardner, C.L. (2018). Effects of a nutrient-enriched water on water intake and indices of hydration in healthy domestic cats fed a dry kibble diet. *American Journal of Veterinary Research*, 79(7), pp.733–744. doi:https://doi.org/10.2460/ajvr.79.7.733.

Zanghi B. Water needs and hydration for cats and dogs, in Proceedings. Nestlé Purina Comp Anim Nutr Summit 2017;15–23.

Zhou, H. and Hu, H. (2008). Human motion tracking for rehabilitation—A survey. *Biomedical Signal Processing and Control*, [online] 3(1), pp.1–18. doi:https://doi.org/10.1016/j.bspc.2007.09.001.

8. Acknowledgements

My biggest thank you goes to my wonderful supervisor Anna Bergh – working under your wing was a phenomenal finale to my SLU adventure. Thank you so much for your patience, guidance, shared knowledge, for accommodating all my doubts and supporting my craft. I'm extremely grateful!

Thank you to my amazing examiner Odd Höglund for all the suggestions, comments, and tips that came literally the next day, it is very appreciated!

Huge thanks go to Moggie – especially Ali Ganjavian and the whole Moggie team! I'm very grateful to be able to do the project on such an interesting and promising technology that will make pets lives better in the future. It certainly raised the quality of my research!

Thank you to the staff of Katthem Uppsala, especially Louise Pettersson and Johanna. Your welcomeness and encouragement are really appreciated! Thank you for all volunteers who were giving me shy smiles of encouragement. I looked forward to visiting the shelter every week for a bit of felinotherapy. Also, Skymning was an experimental unit from heavens, and I miss him dearly.

Thank you to all the survivors of Animal Science programme 2021-2023
The biggest hug goes to Elham – thank you for support, complaining about student struggles together, and sharing your precious heart. You have been a lovely friend on this journey. You deserve the world.

To my lovely partner Robert – thank you for your patience, support, and words of encouragement. I would be much more anxious without your support. Thank you for listening for months about my work and learning to understand it to help me. I appreciate you greatly. And thank you for considering adopting a cat.

I dziękuję moim najbliższym – pomimo, że mało rozumiecie co właściwie studiuję, jestem wiecznie wdzięczna, że zawsze we mnie wierzycie, w moje pasje, marzenia i decyzje. I że czasem ufacie mi w tym bardziej, niż ja ufam sobie. Mam nadzieję, że jesteście ze mnie dumni.

(And thank you to my close family – despite that you understand little of what I am actually studying, I am forever grateful that you can still believe in me, in my passions, dreams and decisions. And that in this you trust me more than I trust myself. I hope I made you proud).

I really did it!
Thank you all from the bottom of my heart,
Daria

9. Popular science summary

Keeping pets healthy is becoming more important among animal owners. With an increase in owners' awareness about the physical and mental health of their companions, there is a growing demand for higher standards of tools to monitor everyday habits, which leads to development and introduction of new technologies into the market. Activity monitors that use accelerometers provide remote insights into the physical activity of animals.

This study focused on registering drinking and littering patterns with an activity monitor in cats to see how effective this equipment is and compared the results with video recordings. Monitoring these habits could assist in detection of early signals of ongoing health problems, such as diabetes.

One cat was equipped with an activity monitor for over 48 days during which thousands of activity data were collected. Selected 671 entries related to drinking and littering were compared with video recordings from a motion sensor camera.

The results revealed that the data from the activity monitor didn't match the video observations from sensor motion camera.

That does not necessarily mean that the technology failed. The potential to use activity monitors to learn more about pets' behaviour and health is still present. However, more research is needed to understand why the results were not as expected, meaning why activity monitor did not register most of the drinking and littering actions. One possibility is that since they are so rare especially in cats, more work is required to train the algorithms to efficiently register these actions. To conclude, activity monitors hold a promise to monitor pets health and well-being.

Publishing and archiving

Approved students' theses at SLU are published electronically. As a student, you have the copyright to your own work and need to approve the electronic publishing. If you check the box for **YES**, the full text (pdf file) and metadata will be visible and searchable online. If you check the box for **NO**, only the metadata and the abstract will be visible and searchable online. Nevertheless, when the document is uploaded it will still be archived as a digital file. If you are more than one author, the checked box will be applied to all authors. You will find a link to SLU's publishing agreement here:

- https://libanswers.slu.se/en/faq/228318.

☒ YES, I/we hereby give permission to publish the present thesis in accordance with the SLU agreement regarding the transfer of the right to publish a work.

☐ NO, I/we do not give permission to publish the present work. The work will still be archived and its metadata and abstract will be visible and searchable.