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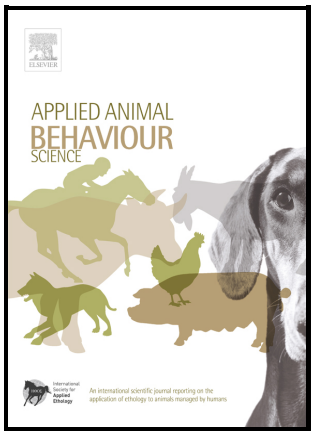

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PII: S0168-1591(22)00072-7

DOI: https://doi.org/10.1016/j.applanim.2022.105614

Reference: APPLAN105614

To appear in: *Applied Animal Behaviour Science*

Received date: 11 January 2022
Revised date: 9 March 2022
Accepted date: 23 March 2022

Please cite this article as: Sarah-Elizabeth Byosiere, Marcelo Feighelstein, Kristiina Wilson, Jennifer Abrams, Guy Elad, Nareed Farhat, Dirk van der Linden, Dmitrii Kaplun, Aleksandr Sinitca and Anna Zamansky, Evaluation of Shelter Dog Activity Levels Before and During COVID-19 using Automated Analysis, *Applied Animal Behaviour Science,* (2022) doi:https://doi.org/10.1016/j.applanim.2022.105614

Evaluation of Shelter Dog Activity Levels Before and During COVID-19 using Automated Analysis

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Abstract

Animal shelters have been found to represent stressful environments for pet dogs, both affecting behavior and influencing welfare. The current COVID-19 pandemic has brought to light new uncertainties in animal sheltering practices which may affect shelter dog behavior in unexpected ways. To evaluate this, we analyzed changes in dog activity levels before COVID-19 and during COVID-19 using an automated video analysis within a large, open-admission animal shelter in New York City, USA. Shelter dog activity was analyzed during two two-week long time periods: (i) just before COVID-19 safety measures were put in place (Feb 26-Mar 17, 2020) and (ii) during the COVID-19 quarantine (July 10-23, 2020). During these two periods, video clips of 15.3 second, on average, were taken of participating kennels every hour from approximately 8am-8pm. Using a two-step filtering approach, a matched sample (based on the number of days of observation) of 34 dogs was defined, consisting of 17 dogs in each group (N1/N2=17). An automated video analysis of active/non-active behaviors was conducted and compared to manual coding of activity. The automated analysis validated by comparison to manual coding reaching above 79% accuracy. Significant differences in the patterns of shelter

dog activity were observed: less activity was observed in the afternoons before COVID-19 restrictions, while during COVID-19, activity remained at a constant average. Together, these findings suggest that 1) COVID-19 lockdown altered shelter dog in-kennel activity, likely due to changes in the shelter environment and 2) automated analysis can be used as a hands-off tool to monitor activity. While this method of analysis presents immense opportunity for future research, we discuss the limitations of automated analysis and guidelines in the context of shelter dogs that can increase accuracy of detection, as well as reflect on policy changes that might be helpful in mediating canine stress in changing shelter environments.

Keywords:
COVID-19, dog behavior, shelter research, applied behavior, computer vision, machine learning

1. Introduction

Each year, more than 4 million dogs are estimated to enter animal shelters in the United States (as reported in Protopopova, 2016). Even for the most well-adjusted dogs the shelter can be an uncomfortable environment (Hennessy et al., 1998). Animal shelters are usually restrictive, both spatially (Beerda et al., 1999; Coppola et al., 2006; Hennessy et al., 1998; Protopopova, 2016; Wells, 2004) and socially (Hennessy, 2013; Shiverdecker et al., 2013), allowing limited contact and interaction with other dogs, humans and the outside world. The sudden loss of control, change in daily routine, as well as the separation from attachment figure(s) can exacerbate anxieties and heighten arousal upon admittance (Hennessy, 2013; Hennessy et al., 1997; Protopopova, 2016; Shiverdecker et al., 2013).

Given the nature of this often jarring experience, various tools to evaluate shelter dog behavior and welfare have been proposed in an attempt to minimize stress and increase the likelihood of adoption (Arena et al., 2017; Barnard et al., 2016; Cafazzo et al., 2014; Haverbeke et al., 2015; Protopopova & Wynne, 2014; Taylor & Mills, 2007). These tools generally consist

of behavioral assessments that evaluate dog behavior, predict adaptability, assess suitability within a given home, and more. However, one problem with establishing comprehensive and accurate welfare assessments for shelter dogs is the immense variability and difficulty of properly assessing the impact of potential individual stressors such as novelty, confinement, separation from attachment figures, noise, etc. Furthermore, the currently available and established protocols are limited by extraneous factors related to shelter resources. Studies conducted by both Barnard et al., (2016) and Kiddie & Collins (2015), indicate that time constraints, limitations in staff availability, and the complexity of the evaluation itself can influence effective implementation, especially routine use of these welfare assessment tools. While multiple welfare assessments have been developed, these limitations pose a problem in their systemic applicability (Menchetti et al., 2019).

An alternative, and perhaps more easily implementable proxy measure for behavior, welfare, and possibly stress, is dog activity level. Accelerometers or activity collars can be used to collect activity level measurements, like active/inactive or step count (for a review of activity collars available see Belda et al., 2018). To date, studies using activity level monitors have demonstrated a correlation between shelter dogs activity levels and behavioral and physiological indicators of stress, including impact of kennel size (Bebak & Beck, 1993; Campbell et al., 1988; Neamand et al., 1975), length of stay (Protopopova et al., 2014), and different enrichment techniques (Graham et al., 2005; Gunter et al., 2019). Compared to owned dogs, shelter dogs vary in their activity level patterns. Hoffman et al., (2019) evaluated activity levels for 19 owned dogs and 19 shelter dogs and found that shelter dogs were more active than owned dogs during the first three quarters of the day, whereas owned dogs were more active than shelter dogs during the final quarter. Furthermore, in an assessment of sleep and resting behavior in shelter dogs,

Owczarczak-Garstecka & Burman (2016) observed that an increased proportion of daytime resting behaviors was significantly associated with a positive judgment bias and fewer repetitive behaviors. Together, these results suggest that activity observed during the day might be an indicator of poor welfare.

While strides have been made in evaluating the welfare of shelter animals, the current COVID-19 pandemic has recently brought about new issues and considerations. At present, most studies have focused on owner-reported assessments regarding the welfare of owned pet dogs. Two studies assessing the effects of the first lockdown in the UK found that dog's routines changed (Christley et al., 2021) in a negative way (Shoesmith et al., 2021) during COVID-19. Pet dogs were reported to have spent more time with their owners, less time interacting with other dogs, and were walked for shorter times, less frequently, than before the COVID-19 lockdown (Christley et al., 2021). Furthermore, the impact of COVID-19, regarding changes in human health, movement, and behavior seems to have influenced owned pets (Jezierski et al., 2021). In an international online survey, Jezierski et al., (2021) reported that 75% of dog owners reported no changes in their dog's behavior during the COVID-19 pandemic. However, owners who experienced a pandemic-related lockdown or quarantine were almost two times more likely to indicate behavioral changes in their dog, highlighting more negative changes in behavior than might be expected by chance.

While assessments regarding the impact of COVID-19 on owned pet dogs have been conducted, few studies have investigated the welfare and behavior of shelter dogs during the COVID-19 pandemic. Again, most of these studies currently represent survey-based designs. Morgan et al., (2020) investigated how people perceived and acted during the COVID-19 pandemic social isolation, specifically relating to dog adoption and abandonment, examining the

bidirectional relationship between the well-being of dog owners and that of their dogs. Overall, the interest in dog adoption and the adoption rate increased significantly during COVID-19, while abandonment did not change. In perhaps the only published study to directly evaluate the impact of COVID-19 on animal shelters, Gomes-Neves et al., (2021) evaluated changes observed in Portuguese animal shelters. Via a survey sent out to various municipal and association-based shelters, the researchers found that shelters generally reported a reduction in exercise and interaction with animals, likely caused by a lack of resources, on-site staff and volunteers, and policies regarding confinement related to zoonotic disease transmission. Together, these results highlight the various ways people believe the COVID-19 pandemic may have affected shelter dogs during COVID-19.

To the best of our knowledge, no observational assessments evaluating the differences in the activity of shelter dogs before and during COVID-19 have been conducted. In this paper, we aim to fill this gap by investigating the activity levels of shelter-housed dogs, in kennels, before and during COVID-19 using two methods of analysis. Specifically, we evaluated manual coding of behavior compared to an automated video-based analysis using a self-developed tool applying computer vision techniques. Automated analysis has significant benefits compared to manual coding due to the ability to process large volumes of data, as well as its potential for better precision and consistency. We had two hypotheses in this research: 1) differences in shelter dog in-kennel activity could be observed before COVID-19 and during COVID-19 and 2) automated analysis could be a suitable hands-off tool to automatically monitor activity in an active animal shelter for detecting these differences.

2. Material and Method

2.1 Shelter Before and During COVID-19

Animal Care Centers (ACC) of New York City (NYC) is New York City's (New York, USA) open-admission animal shelter system, taking in around 20,000 animals each year, supporting NYC's five boroughs. For this study, we evaluated dogs housed in two holding rooms located at the Manhattan Care Center location. All dogs were housed per ACC practices and policies. In both holding rooms, dogs were housed individually in metal Shor-Line kennels of varying sizes. Steel dog runs (1.5 meter (m) long x 0.9 m wide x 1.8 m high) with back-to-back or side-to-side transfer doors to give each dog two runs when population allowed. In this configuration, dogs were given their beds (typically Kuranda beds with a blanket) and their food and water bowls on one side, with the other side left open for moving around and eliminating. When space did not allow transfer doors were closed and dogs were given only a single kennel side with a bed and food/water bowls. All dogs participating in this study were housed individually, and all were cared for according to the same routine shelter protocols. All incoming dogs were checked by a veterinarian upon intake (within the first 24 hours. Additionally, a formal behavior assessment based on all known information (e.g., reported history, handling assessment at veterinary intake exam, and playgroup) was made by the behavior team 24-72 hours after intake. SI in the supplementary material presents more complete subject demographic information.

2.1.1 Before COVID-19

Before COVID-19 the shelter was open from 8:00 to 20:00 hours for animal surrenders and 12:00 to 20:00 hours (weekdays)/10:00 to 18:00 hours (weekends) for adoptions. Lights went out overnight from 22:00 to 6:00 hours to assist with sleeping. Morning feeding occurred between 6:00 and 7:00 hours, and kennel cleaning started at 8:00 hours and lasted until 12:00 hours, with regular spot cleaning throughout the rest of the day. Dog playgroups ran from around

9:00 to 11:00 hours. Evening feeding happened between 16:00 and 17:00 hours. Shelter volunteers arrived throughout the day to walk dogs (approximately, 2-3 times a day for 5-30 minutes). The shelter was staffed 24 hours a day, and open to the public during adoption hours.

2.1.2 During COVID-19

From April through August 2020, the shelter was closed to the public and to volunteers. The staff were split into non-overlapping teams for the health and safety of humans and animals, and these split teams stayed in place until July. The playgroup program was minimized due to both staffing shortages and a less social population of dogs. A nap time was introduced every day for one hour in the afternoon. Typically, this took place from 13:00-14:00 or 14:00-15:00 hours. During nap time, the lights were turned off in all animal rooms and staff were asked to avoid entering the rooms. Mealtimes remained the same, as did overnight lights out policies.

2.2 Subjects

Overall, 118 dogs were video recorded, 77 dogs were recorded before COVID-19 and 41 dogs were recorded during COVID-19. Because the shelter was actively adopting out dogs during both periods, we could not compare the same dogs in before and during COVID-19 time periods. This was due to the positive reason that dogs did not stay in the shelter long enough to span both periods. Instead, we filtered both before COVID-19 and during COVID-19 samples using a two-step approach, consisting of (1) real-world considerations, and (2) statistical analysis. First, we filtered out any dogs who were in the shelter only for brief stays, i.e., whose total stay in the shelter amounted to no more than two days. This led to reducing the before COVID-19 sample to include 46 dogs, and the during COVID-19 period to 17 dogs. Second, we identified outliers by calculating the interquartile range and using that to identify outliers defined as any ‘stays’ smaller than 1.5 Q1 or longer than 1.5 Q3. This further reduced the before

COVID-19 sample to 42 dogs and had no effect on the during COVID-19 sample (N=17). Following this filtering process, we sorted both samples by number of days of observation in the shelter and used the smaller, during COVID-19 period, sample as a guideline for matching the most similar before COVID-19 sample in terms of days. This led to a matched N1/2=17 sample detailed in Table 1 which we then used for statistical analysis.

2.3 Data Collection and Preprocessing

The current study is observational with no direct manipulation or invasive sampling. The videos analyzed as a part of this project had already been recorded for a separate study investigating the effects of different kennel environments on canine stress. The project was approved by NYC ACC.

Videos analyzed as a part of this project were recorded using 14 Blink Cameras for four weeks, two consecutive weeks before COVID-19 (Feb 26 - March 17, 2020) and two consecutive weeks during COVID-19 (July 10 - July 23, 2020). Each day, recording samples were automatically collected at the beginning of each hour, approximately between 8:00 and 20:00 hours. Recordings lasted 15.3 seconds in length on average (Table 2 presents further details). Figure 1 demonstrates the position of the cameras in relation to the kennels in one of the rooms, while Figure 2 shows example frames from four different kennels.

2.3.1 Manual Coding

The manual analysis, to which the automated analysis presented here, was conducted as a part of another study evaluating in-kennel stress behavior of shelter dogs. The following categories were included for manually coding activities: walk, stand, sit, lie down, cower, lean on door. More categories were manually coded, but that analysis is beyond the scope of this

paper and relates to a different research question. Overall, 2,232 videos were manually coded by eight coders, naive to the research question. Coders varied in the number of videos they coded ranging from 39 to 453 and averaging 275 videos. A Gwet's AC1 analysis of reliability was conducted comparing each coder to a reference coder (the coder who coded the highest number of videos). Based on Gwet's AC1 the reliability across coders was almost perfect at kappa ≥ .89 (ranging from .89 to .93).

2.3.2 Automated Evaluation of Activity

We used a self-developed tool for automatic evaluation of activity. The input to the tool is a video (associated with kennel number, date, and time; see example frames in Figure 2), taken by cameras located as shown in Figure 1. The output is a quantification of dog movement on the video using 'step count', where a 'step' is an elementary unit of dog movement detected between frames, exceeding a certain threshold. This step count metric is implemented by combining neural network detection (using the ResNet50 neural network - See this link for technical details) with classical image processing techniques.

Since there is no direct mapping between the metric described above and manual coding categories, we used the following approximation for validation of the metric. Videos were divided into two classes: *active*: having at least one of the categories Walking or Jumping, and *non-active*: having none of these categories. A Random Forest classifier based on the step count metric reached 79% accuracy in predicting the (ground truth) activity presence (classes of *active*/*non-active*). Therefore, the step count metric provides sufficient information for differentiating with 79% accuracy between active/non-active states of the dogs (as detected by the human coders). Other, more complicated metrics employing people detection, in addition to dog detection, were also investigated at this point reaching up to 81% accuracy using Bagging

Classifier-SVC, but we opted for the step count metric due to its simplicity and intuitiveness of use. Henceforth we refer to the (binary) classifier as the activity presence metric.

3. Results

The selected sample resulted in 108 data points before COVID-19, and 144 data points during COVID-19. For each of the 252 videos, we calculated (i) step count (numerical), and (ii) activity presence (binary). Step count was averaged per day, leading to a mean 54.9 steps (25.4, min=4.5, max=116) before COVID-19, and a mean 77.6 steps (40.3, min=2.33, max=218) during COVID-19. A Shapiro-Wilk test of normality indicated non-normal distribution ($p<0.01$); thus, we used a Mann Whitney U test to assess the difference between before COVID-19 and during COVID-19 activity levels. For activity presence we computed a contingency table contrasting the number of non-active and active data points before COVID-19 (resp. 1036 and 91) and during COVID-19 (resp. 1012 and 191), and then used a χ^2 test to assess difference in activity presence.

- Step count was found to be significantly lower before COVID-19 (median=56.7) than during COVID-19 (median=75.7) (two-tailed Mann Whitney U=5061, $p<.00001$), visualized in Figures 3 and 4.
- Activity presence was found to be significantly (φ=-0.12) lower before COVID-19 than during COVID-19 ($\chi^2(1) = 33.3$, $p<.0001$).

We further investigated differences in activity through daily time periods (8:00-10:00 hours in the morning, 14:00-16:00 hours in the afternoon, and 18:00 to 20:00 hours in the evening) visualized in Figure 3. Figure 3 shows how activity changed during the day, in terms of average step count, during COVID-19. Figure 4 groups the activity in terms of step count into morning, afternoon, and evening, indicating that morning remained the most active time of the day, both before and during COVID-19. Nap times during COVID-19 can be seen as the lowest

point of activity during the day.

4. Discussion

The main aim of the present investigation was two-fold: 1) to evaluate the activity levels, in terms of active/non-active and step count, of shelter dogs housed in kennels, before and during COVID-19 and 2) to assess the suitability of using an automated video-based analysis based on machine learning techniques compared to manual behavioral coding. First, we found differences in shelter dog activity during the two time periods (before COVID-19 and during COVID-19). During COVID-19, dogs took significantly more steps within the kennel and demonstrated a significantly higher presence of activity. Second, automated analysis, and specifically, step count is a useful and easily implementable metric to automatically monitor dog activity levels in an active shelter based on video recordings, reaching 79% accuracy in active/non-active classification as detected by human coders. Together, these results suggest that during COVID-19, dogs were more active in the kennel than before COVID-19 and automated analysis may be a useful method for hands-off coding in active, operating, animal shelters. More research is needed to further investigate metrics to be used in automated analysis of activity in shelters, and the ways in which they can be effectively validated against human coding.

An additional interesting result relates to the effect of nap times. During COVID-19, nap times were instituted. The effect of nap times during COVID-19 can be seen as the lowest point of activity during the day, suggesting that “quiet hour” periods, with limited interruption, can be helpful in encouraging rest by reducing kennel activity. This is in line with the findings in (Houpt, 2019; Houpt et al., 2019), that investigated the night-time behavior of sheltered dogs and the effect of artificial light on their sleeping patterns, finding no significant difference in time spent lying with or without light, concluding that well-stimulated shelter dogs slept soundly in

the absence of people. However, while decreasing activity levels were observed in the afternoon before COVID-19, a constant average movement level was observed during COVID-19. This suggests that nap times are not solely enough to reduce activity in the kennels, and other enrichment and exercise activities, such as playgroups and walks should be used in tandem to help further reduce activity in the kennels.

To our knowledge, this study is the first to investigate the effect of COVID-19 on in-kennel behavior of shelter dogs using objective measures. The findings presented in this manuscript are fortuitous, as video collection for a larger project evaluating in-kennel stress behavior began a few weeks before the COVID-19 lockdowns occurred globally. Thus, a snapshot of the changes observed in dog behavior, in this particular shelter, brought on by COVID-19 can be evaluated. However, we emphasize that given the applied nature of this study, as well as the tumultuous societal circumstances that occurred surrounding this event, that these results, and the proposed implications, may not be generalizable.

While there are likely multiple explanations for the result we observed, we believe that these findings may stem from changes in the shelter environment because of city-wide COVID-19 restrictions. In the middle of March 2020, right around the time of the New York City stay-at-home orders (March 20th, 2020), NYC ACC was required to limit regular access to the shelter. It is important to note that this shift occurred after the before COVID-19 sample was collected (February 26th-March 17th) but well before the during COVID-19 sample (July 10th-23rd). Given these protocol changes, dogs in the before COVID-19 sample likely had increased access to activities such as play groups, walks from volunteers, and the presence of possible adopters visiting the kennel space. In fact, such a result is reported in Gomes-Neves et al., (2021), where more than a third of shelters surveyed reported a reduction in exercise and interaction with

animals. Therefore, it is perhaps not surprising that the dogs during COVID-19, were more active in their kennel as these various (possibly enriching, but also possibly stressful) interactions may have led to reduced activity in the kennels before COVID-19.

This unexpected circumstance, which drastically altered human behavior seemingly overnight, also appears to have affected shelter dog behavior. While changes in behavior were expected, the directionality of some results was particularly interesting. Dogs in kennels have been commonly reported to spend most of their time inactive (Hetts et al., 1992; Hubrecht et al., 1992; Hughes et al., 1989; Yeon et al., 2001). Thus, one may have predicted that shelter dog activity within the kennel would have decreased during COVID-19 due to a presumed decrease in staff and adopter activity. That being said, it is possible that the dramatic and sudden change in human behavior and daily routine, brought on by an unprecedented pandemic, may have contributed to the increase in in-kennel activity observed during COVID-19. Control and predictability, especially when faced with aversive stimuli, is integral to mediating a dog's stress response (Dess et al., 1983). The sudden changes in staffing, prospective adopter visits, and overall human presence in the shelter may have served as an adverse change, increasing stress in the kennels, and thus overall activity. A recent study evaluating the effect of human presence on shelter dog behavior, observed that dogs spent significantly more time on their bed and resting when a human was present (Tuozzi et al., 2021). Given that shelter dogs are more likely to approach unfamiliar people and form attachment bonds rapidly (Barrera et al., 2010; Gácsi et al., 2001), these findings may suggest an increased need for social contact for dogs confined in kennels (Tuozzi et al., 2021).

It is, however, important to note that the current study looks only at activity in the kennel (step count and activity presence) which may or may not include stress-related activity. While, in

other studies, activity levels in shelter dogs have been correlated with both behavioral and physiological stress, this was not possible in the present investigation. Therefore, future studies should aim to evaluate if certain active and non-active behaviors (e.g., pacing, lip-licking, whale eye) can be used to further support and clarify the current results. Regardless, even measuring more specific stress-related behaviors may not help further clarify these results as the presence or absence of stereotypies and repetitive behaviors are also not indicative of "good" or "bad" welfare (Protopopova, 2016). It is important to highlight that stereotypies also are observed in dogs living in home environments, where presumably welfare is substantially improved compared to shelter. Thus, stereotypies can relate to physiological factors, independent of environment.

Finally, another interesting question would be whether pet dogs also experienced a change in activity during COVID-19. Most owners believe that their dog's routine has been changed due to lockdown restrictions (Christley et al., 2021), and some studies have evaluated separation-related behaviors during this time (Bleuer-Elsner & Masson, 2021; Harvey et al., 2022). However, it would be useful to evaluate whether activity levels of owned dogs while at home have also increased, similarly to the findings of our study. A comparative assessment of shelter and owned dog activity would allow us to further evaluate the effects of COVID-19 on dog behavior. These changes to dog management, regardless of whether they are in a home or in a shelter, may have longer-term welfare implications such as increased likelihood of dogs displaying separation-related behavior as lockdown measures relax.

4.1 Technical Difficulties and Solutions

The active shelter setting presented several issues for detection accuracy of dog detection in the automated analysis. We discuss next how we dealt with these technical challenges and

provide some general guidelines for future planning of studies employing automated monitoring in shelter environments. The main sources of errors of misclassification by the model were:

- *Dogs behind bars were not recognized.* As quality images of dogs in kennels, specifically located behind bar-like barriers, are hard to find, this problem was overcome by augmenting dog images with bars in the training set.
- *Moving people were classified as dogs.* In various instances, moving people entering the frame were classified as dogs. This issue was dealt with by manually annotating areas outside the kennels, where the dogs could not be found, thus reducing this type of error.
- *Multiple dogs*. Several issues were discovered related to more than one dog per kennel: multiple dogs could be detected as one, or one dog could be detected as two different dogs. Dogs were singly housed in kennels, so this was always a misidentification. This issue usually could be filtered out as detection outliers, and by simple preprocessing and smoothing these outliers could be removed.
- *Static objects in kennels.In the kennel, various items were placed. Blankets that matched traditional dog coat colors were problematic and caused false positive dog detection*. As they were static on all the frames, we could manually locate and remove them.
- *Static objects on bars.* Information sheets (e.g., kennel cards) hanging on the kennel doors sometimes compromised dog visibility. This problem could be solved by training additional classifiers for their detection and removal.
- *Challenging camera angles.* While cameras were placed directly across from kennels in multiple areas of the rooms, accuracy was sometimes compromised by certain

angles. This could be handled by adding more cameras and running pilot recordings before starting the monitoring.

When planning a study with automated activity monitoring, it is crucial to take into consideration camera angles that always maximize the visibility of the dog. Smoother detection can be achieved by removing all “confusing" objects such as blankets from the kennel and information sheets from blocking the view. However, this is not very practical and possibly presents additional welfare concerns relating to sterility of the environment. Therefore, attention should be paid to the placement of the camera and the types of items placed in the kennel. For example, the colors of the blanket could be non-typical of dog fur, and the placement of kennel cards could be moved to a more suitable location. Finally, if possible, it is recommended to avoid placing a camera in a position where humans can come between it and the dogs, possibly on the inside of the kennel, out of reach from the dog. Future studies should also explore how the shelter team can be more actively involved in preparing the shelter for automated video monitoring, while also considering issues of security and privacy.

5. Conclusion

Due to the nature of the domain, solutions to evaluate the welfare of shelter dogs need to be practical, cost-effective, and easy to implement by busy shelter management teams. We hope this paper is only the beginning of the discussion - both within and between the scientific community shelter professionals - on the challenging issue of automating shelter dog behavior assessment and monitoring.

In this paper we highlighted various changes observed in dog activity before COVID-19 and during COVID-19 when evaluating the suitability of a video-based analysis based on machine learning techniques. We also present and evaluate simple metrics to be used in the

context of automated analysis, and relevant technical considerations that warrant further investigation in any future studies considering the use of automated video analysis in shelter environments. It is important to consider and further explore the generalizability of the metrics to different shelter environments, so that there is a systematic way to compare measurements from different studies and shelters. This is one of the most immediate future research directions we plan to undertake.

Acknowledgements

The research was partially supported by the grant from the Ministry of Science and Technology of Israel and RFBR according to the research project no. 19-57-06007 and the Animal Behavior and Conservation MA Program's Thesis Research Grants. The authors would specifically like to thank Animal Care Centers of NYC for their willingness to be involved in this project. Finally, this work would not have been possible without the amazing team of manual video coders who contributed to this project. Thus, the authors wish to thank Sasha Montero, Sasha Prasad, Aiman Haider, Bryan Perez, Lorraine DiSano, Caitlyn Thai, Rachel Rodin, and Anne Castiglioni for their efforts.

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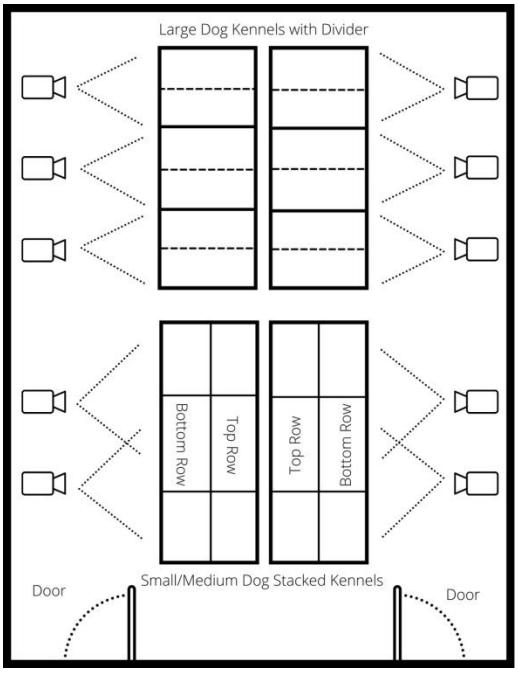

Figure 1. Top-down depiction of the kennel placement and the camera locations used to record the dogs in the shelter.

Figure 2. Example video frames from four different kennels. Active: (A) jumping; (B) walking; Inactive: (C) sitting; (D) lying.

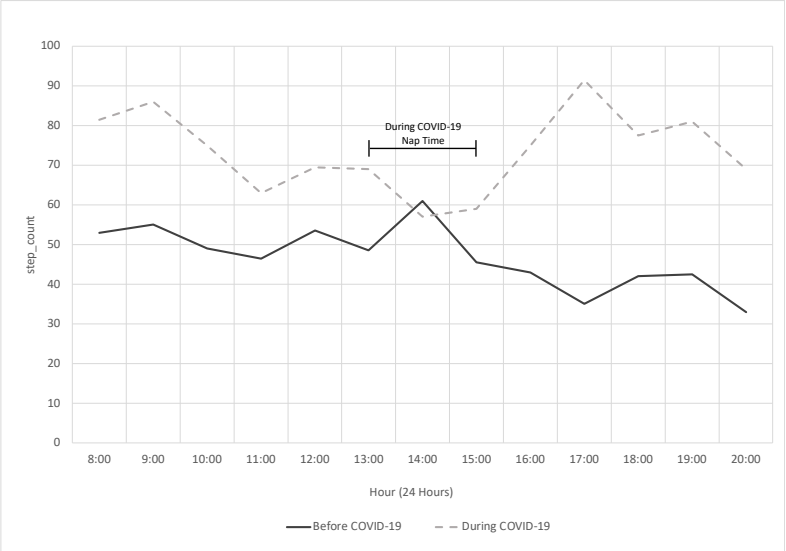

Figure 3. Average step count over hours (using a 24-hour clock) of the day before COVID-19 and during COVID-19. Note the bracket indicates the nap time instated by the shelter during COVID-19.

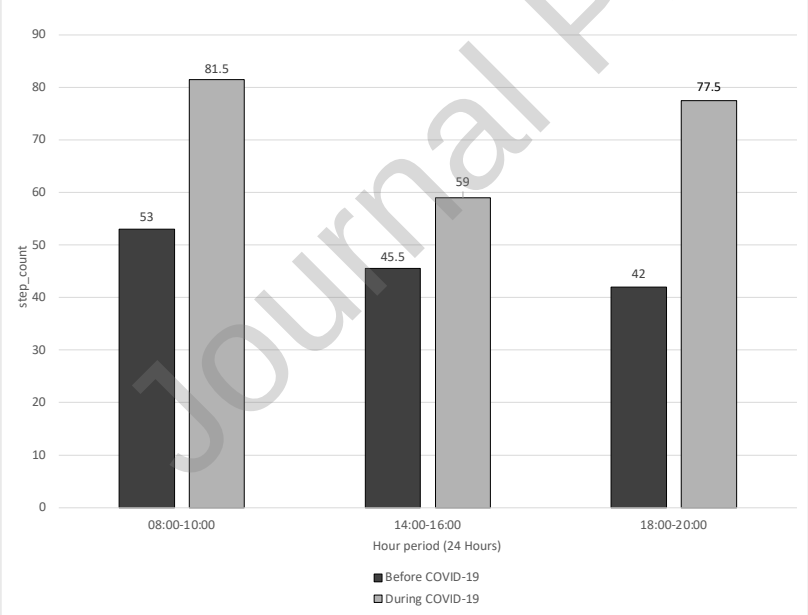

Figure 4. Average step count over three 2-hour segments of the day (using a 24-hour clock) before COVID-19 and during COVID-19, representing morning, afternoon, and evening.

Table 1. *Selected dogs for comparative study defined as their ID number and noting the number of study days they stayed in the shelter*

Before COVID-19 (N=17)		During COVID-19 (N=17)	
Dog ID #	Days Observed in Shelter	Days in Shelter	Days Observed in Shelter
6	9	28	14
21	7	29	14
39	7	52	14
54	7	95	14
117	7	1	12
78	7	26	12
96	7	33	11
115	7	91	8
5	6	104	8
20	6	118	6
36	6	79	6
37	6	44	6
47	6	50	5
85	6	67	5
108	6	42	4
45	5	7	3
82	5	72	3

Table 2. *Summary of video data (after final filtering)*

	Before COVID-19	During COVID-19
Number of videos	1,127	1,203
Number of cameras	12	12
Number of dogs/kennels	17	17
Sum of all videos (min)	197.53	366.39
Average video length (sec)	12.38	18.23

Highlights

- In-kennel shelter dog activity was analyzed and compared before and during COVID-19.
- Automated video analysis of activity levels was validated against manual coding.
- In-kennel activity was significantly lower before COVID-19 than during COVID-19.
- COVID-19 societal changes may have adversely affected shelter dog's in-kennel activity.
- Uncontrollable societal changes add complexity to managing shelter dog welfare.