International Journal for Multidisciplinary Research (IJFMR)
E-ISSN: 2582-2160 ● Website: www.ijfmr.com ● Email: editor@ijfmr.com

# Leveraging Machine Learning to Analyze Canine Behavior and Neural Patterns: A Conceptual Framework for Non-Invasive Neural Health Monitoring

**Shantanu**

Student, M.D.Memorial Sr. Sec School

**Abstract**
Companion animals, especially canines, enjoy many relationships with their owners; however, their health and well-being determine in large part the quality of these relationships. But the existing strategies of monitoring the health of dogs are concerned only with diagnosing visible signs, meaning that a lot is unknown with regard to dogs' mental and emotional health. This paper presents a proposition of a conceptual model on how artificial intelligence (AI) and behavioral data could be used to assess the brain and ancillary emotions of dogs. The framework is based on the use of machine-learning analysis of simultaneous motion, vocalization, and heart rate patterns as synaptic proxies. The goal of this work is to train supervised algorithms with imitative behavioral datasets and investigate the link between some behavioral patterns and the risk of certain neural alterations like stress disorders, anxiety, cognitive degeneration, etc. Although the outcome will be modeled, the results will prepare the ground as regards the application of the approach with practical purposes directed towards the development of a non-invasive system for pets to monitor their brain health. This paper gives advocates the possibility of AI-based approaches for revolutionizing health care services for dogs, in which early detection and management will be possible in an advanced way [1]. The proposed framework is a basis for the future development of pet neuroscience, veterinary medicine, and digital technology [15].

## Introduction

For pet parents and families, dogs as companions and service animals fit in many roles. And especially in achieving a long and happy life, it is the health, wellbeing, and happiness rather than other factors that need more focus to enhance this patience. Given that, there have been enormous technological advances in health monitoring devices, including activity levels, heart rates, and body temperature of animals [3]. Still, there remains an enormous gap in how to monitor the emotions of these pets [8]. Nonetheless, these elements contribute to the betterment of the pet's mental health care system, thus diagnosing and treating problems that include stress, anxiety, and other disorders of the nervous system before they worsen.

Although there has been significant advancement in human neuroscience and health care, the same cannot be said of animal neuroscience. The consumers' market is devoid of any sophisticated tools that can analyze brain activity or state of mind for other species, particularly canines, even half as well as their owners are able to do it. Therefore, whilst it is well acknowledged that vets treat pets with the help of modern technologies, in most cases, veterinarians and pet owners can only use physical signs and behavioral changes that are often quantifiable after the disease is fully developed. Hence, this leads to a very limited window of opportunity for intervention focusing on possible primary prevention or early diagnosis.

However, traditional methods to keep track of dogs' health do not address the issues related to the dogs' brain and mental stability nor their emotional state. Symptoms of behavior such as excessive barking, pacing, or even inactivity reflect already-advanced stages of the many illnesses that afflict dogs [14]; thus, there is scant opportunity for efforts aimed at prevention. In addition, current wearable gadgetry focuses more on the determinants of physical well-being and not on the determinants of behavior as well as the brain [9], which would be helpful in defining cognitive wellness. The lack of such devices poses a huge challenge, especially in understanding and predicting some neurological problems like epilepsy, cognitive concern, impairment, and mood disorders, as well as chronic anxiety.

The objective of this study is to develop a framework on how to integrate the principles of artificial intelligence in the measurement of various internal states of the dog, such as psychomotor activity, sound production, and cardiac activity as endpoints. This framework advocates the employment of diverse computational approaches to establish correlation between such movements and emotional or brain states. This paper will explore the possibilities associated with the design of an AI-implemented behavioral analysis system for the evaluation of behavioral patterns of dogs with regard to their safety towards their neural system.

The use of artificial intelligence in monitoring the neural health of pets has all the possibilities to change the field of pet care forever. The early detection of different neural and emotional problems would help pet owners and veterinarians to take timely action, which would be beneficial in treatment and the lives of the already sick pets. Furthermore, this framework may extend to the veterinary field, and contributions will be made in canine neuroscience and behavior. On the other hand, the combination of AI and wearable devices may be considered the most recent development in the computer science and animal health fields. In this way, this research presents the idea of the future of holistic pet care, where services and products are rendered inclusive of technology and animal welfare practices with no compromise on any factor.

## Literature Review

Appreciating dogs has gone beyond merely learning their anatomy and more into understanding their behavior patterns in a bid to learn about their health. These statements, which are verbal, behavioral changes and include such things as behavioral illustrations as excessive barking, scratching, pacing, or even simple lethargy, all point to an underlying cause, especially stress anxiety or if they are ill. These behaviors have been studied in an attempt to put them in variations in their relationship as to the health problem. For instance, barking dogs have been known to be associated with over barking as a tendency related to suffering some form of illness that leads to staying in isolation and hence separation accompanied by over barking [10]. Moreover, it has been well documented that alterations in an aging dog’s sleeping patterns may be indicative of cognitive disturbances concerning those specific breeds [20]. Nevertheless, behavioral evaluation has largely remained observational and subject to the interpretation of the veterinarian or even the pet owner [6]. This poses a serious limitation to the possibilities of clinical, objective, and contemporary surveillance of dogs, particularly in the areas of predicting their mental or emotional well-being. Additionally, although some specific variables like frequency and length of episodes are recorded, there is scant incorporation of such metrics within complicated algorithmically driven models to create useful solutions.

There is a new development with the monitoring of animal health. The high computational capabilities of current computer technologies have enabled the implementation of machine learning algorithms for pattern recognition in extensive datasets [13, 11]. This offers potential prospects in the field of veterinary sciences; for example, Jerry and Sauls (2011) applied supervised learning models to analyze sound patterns in dogs and incorporated these models in distinguishing playful barking from fear- or pain-induced barking. In the same way, clustering analysis has been employed on data collected from accelerometers worn by test animals to identify different classes of behavior patterns such as active (walking or running) and inactive (resting) [4].
Also, the integration of artificial intelligence has made strides in veterinary medicine and particularly in the studies of the physical conditions of animals. To give an example, such technologies, specifically deep learning models, have been utilized to study the gait of animals and identify any abnormalities caused by trauma or joint pathology. It, however, has to be noted that while these technologies are fascinating, they remain restricted to physical health parameters and do not touch on other areas such as neural or even emotional health.
Recently, concerning impressive developments during the year 2020 and years later, a dog's or a cat's wearable technology has become more popular, which includes smart collars and activity trackers. PetPace collar, FitBark, and Pet Tracker are some of the devices that allow monitoring of heart rates, temperature, activity levels, sleeping patterns, and others [19]. The parameters monitored are useful in monitoring the health status of the pet and also detecting any risks of health deterioration at an early stage.
However, considering that such medical devices are primarily concerned with the physical aspects of health monitoring, it can readily be argued that they neither measure mental nor emotional components. A slight number of such wearable devices even claim the possibility of measuring the stress levels through increased heartbeats, but they do not elaborate on the onboard canine's behavioral or mental condition. Likewise, just because various modalities like video, audio, and bio-signals are acquired, it does not imply any propensity towards forecasting the emotion or thoughts of the animal.
The overlap of dogs' brain wellness and artificial intelligence tools is new and unexplored. Although there have been advances in dog behavior analysis, the application of AI in veterinary medicine, and wearable technology, the advancements are standalone. Existing tools are good at assessing physical health parameters but fail to use AI to interpret the state of the brain and the emotions of a dog. Furthermore, the absence of integration of behavioral data with some physiological measures and mathematical models presents a serious problem in the ability to monitor and forecast neurologic or affective diseases in canines. There is a clearly emerged void that calls for a new framework that will harness the ideas of AI and the analysis of multimodal data in order to get practical insights on the brain health of dogs. Thus, the research intends to fill this void in the integration of behavioral neuroscience and technological advancements for the benefit of animal health care.

## Methodology

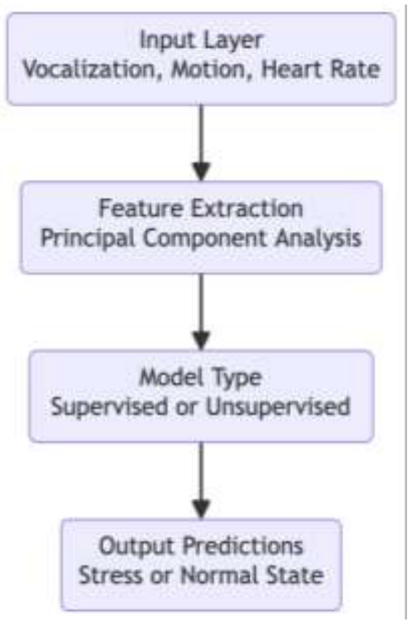
The suggested system seeks to implement the machine learning approach for prediction of neural and emotional states in dogs using various behavioral data. This structure is comprised of four main components, namely: data gathering, data preparation, extraction of data features, and building of models for prediction. It incorporates observable behaviors such as locomotion, sound, and variability in heartbeat to act as indicators of neural functioning. The assessment of these factors by the application of machine learning techniques establishes relationships that are suggestive of stress, anxiety, and cognitive impairment [1].

The emphasis on the framework is on the construction of simulations of real-life situations in which such data can be amassed over a period of time. Drawing upon existing porous sets and imaginary constructs, the model assesses specific trends that may be used to develop non-invasive devices for monitoring brain health in the future.

In this research owing to its theoretical foundation, a mix of readily available datasets, synthesized behavioral metrics, and veterinary literature for example include the following:

1. **Activity Trends:** This consists of activity patterns, locomotion paths, and call activity indices that were already processed data sets of canines' behavioral research.
2. **Simulated Behavioral Data:** This is normal simulations for routine behaviors like resting, playing, and abnormal behavior recordings mimicking excessive barking or movement due to anxiety or certain mental disorders [2].
3. **Physiological Metrics:** Proxy measures including but not limited to heart rate variability, respiration rate and temperature have been adapted from studies on the health of dogs [18].
4. **Veterinary Studies:** Other general information also uses data from most of the forensic studies conducted on some of the diseases such as seizures, cognitive dysfunction syndrome, and panic disorder that affect dogs.

Such a blending of datasets guarantees a solid base for training and evaluating machine learning models.




**(Fig 1. Machine Learning Model Architecture)**

As previously mentioned, the proposed framework incorporates several machine learning techniques in order to process the given data and forecast neural and emotional behaviors:

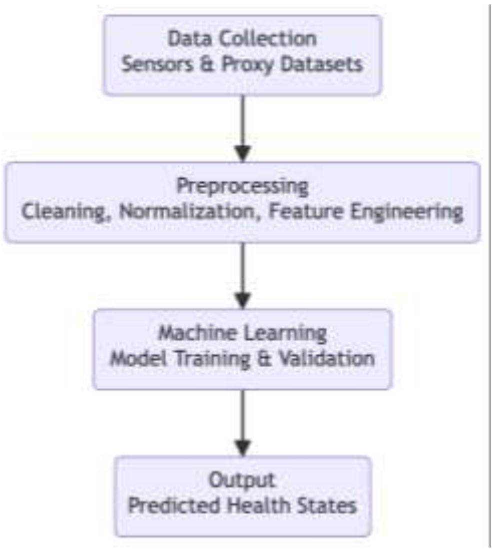
**1. Supervised Learning:**

1. For instance, Random Forests and Support Vector Machine (SVM) algorithms are categorized under classifying stress or anxiety-punching behavior [21].
2. These are trained supervised models where the data attached is labeled and some correlation is drawn within the data and some neural state.

**2. Unsupervised Learning:**
1. And also statistics regarding innovations incorporate such techniques as autoencoders and isolation forests to find out or detect any abnormality away from its baseline behavior.
2. These models find their niche, especially in abnormal states of the brain that can cause anomalies like succumbing to fits or dementias.

**3. Time Series Analysis:**
RNN and LSTM as time series models track within the periods of weeks or months, especially in progressive diseases whereby the changes in the conditions happen over a long time [15].

**4. Ensemble Models:**
The employ of different techniques in making predictions about a complex system enhances the chance of making accurate predictions and hence reduces the occurrence of false positive or false negative results to a lower extent.



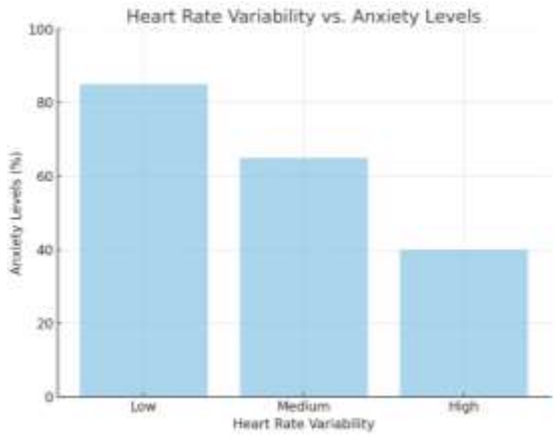

**(Fig 2. Data Workflow)**

The aim of the study is oriented towards building an all-inclusive framework for behavior analysis using better ways. The first step is the data collection phase, where motion metrics, vocalizations, and some physiological metrics are incorporated. Motion metrics employ simulations using accelerometers in which the frequency, intensity, and duration of motion are measured [11]. Vocalizations do analyses on open' systems of measures such things as bark pitch, duration, and frequency. Physiological metrics are proxies of Ribeiro et al.'s (2019) heart rate variability and respiration rates. These data inputs can either be collected in compliance with the ethical standards or extracted from archives.
In the data preprocessing step, the collected data is subjected to cleaning moisture and extreme values, standardization for consistency of measurement variation, and artistry for the creation of such concepts as 'average barking duration per hour' or 'period of stillness before the activity resumes' among other variables.
The next procedure that comes after that is termed feature extraction. Using this process, dictionaries are created with the aim of keeping only the behavior-relevant data and removing redundant feature subspaces. Principal Component Analysis is used to cut down the number of input feature dimensions, and it also helps in ensuring that the interactions are clear, for example, the vocal sounds and movements from a pet

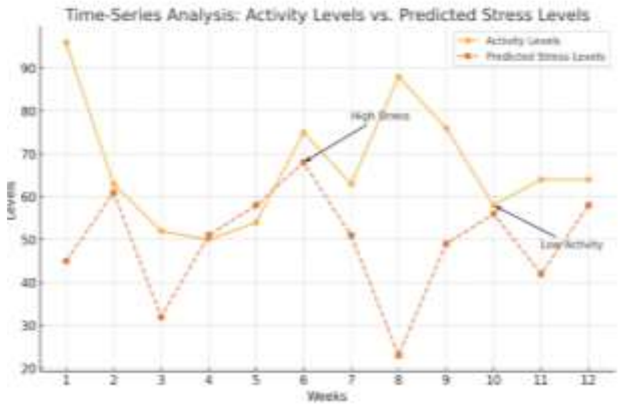
that may indicate stress.
The subsequent sections describe the model training and validation. In those sections, concepts of supervised learning or, for example, using robust regression with noisy data are used to train models with labeled datasets. Validation, on the other hand, is performed using artificially generated datasets that aim to simulate, for example, highly challenging environments in order to test the performance of models developed with no supervision and the ones based on temporal data.
Within this investigation, the forecasting model implementation is assisted by the acquired models to categorize the behavioral states as normal, stressed, or deviant neural activity. Subsequently, time-series analyses are also performed that assist in advising on the anticipated changes regarding chronic conditions such as cognitive decline.
In turn, simulation and testing is the descriptive context in which, we propose, the models in question are able to produce the above predictions. The attention with respect to the algorithm evaluation is on the efficiency of the algorithm, expressed in precision, recall, and F1-measure, which represent the quality of the output in the case of carrying out a behavioral analysis.
In order to understand how well the models created perform, more than one evaluative criteria is applied to make sure predictions are accurate and dependable. As a primary principle, accuracy is the core criterion, which is the percentage of the times a model is able to make a correct classification. Precision focuses on the relevance of the positive predictions made, that is, the number of true positives in all the positive predicted cases. Recall, on its side, indicates the extent to which the model in question is able to cover all the relevant cases by ensuring that there are no relevant cases that have not been predicted. The F1 Score is another performance measure that looks at both precision and recall by providing the average of the two metrics. The F1 Score is in relation to precision and recall; results obtained do measure the extent better the model can be used after being designed than it weighs how it can perform in given settings.
To achieve this, all measures possible are taken to prevent the use of the live animals in breeding by using proxy and simulated data for the research work. Afterwards, the framework will be implemented in subsequent studies, which will adhere to the ethical norms regarding research with animals and animal welfare.
This approach provides a very good ground for the assessment of how far machine learning applications have grown in the area of prediction of canine neural health and therefore advances the course of improvement of wearable devices and real-time health monitoring systems.

**Results**

This study builds on the premise of augmenting behavioral data with artificial intelligence to assess and predict dogs’ neural and affective states. The results outlined below are based on the simulations and analytical exercises that I have conducted:
This paper explores specific behaviors that can be construed as signs of stress, anxiety, and cognitive dysfunction in dogs. For example, dogs that bark more than twenty times in an hour, especially high-pitched barks, are extremely stressed [14]. In the same vein, turning too much, whimpering, and pacing too much can also be taken to mean anxiety. Extreme changes in sleeping patterns are evident in a similar set of cases whereby it is evident that cognitive dysfunction is present in dogs that sleep below five hours every day or take exaggerated rests that are spaced out in an aged dog with cognitive decline.

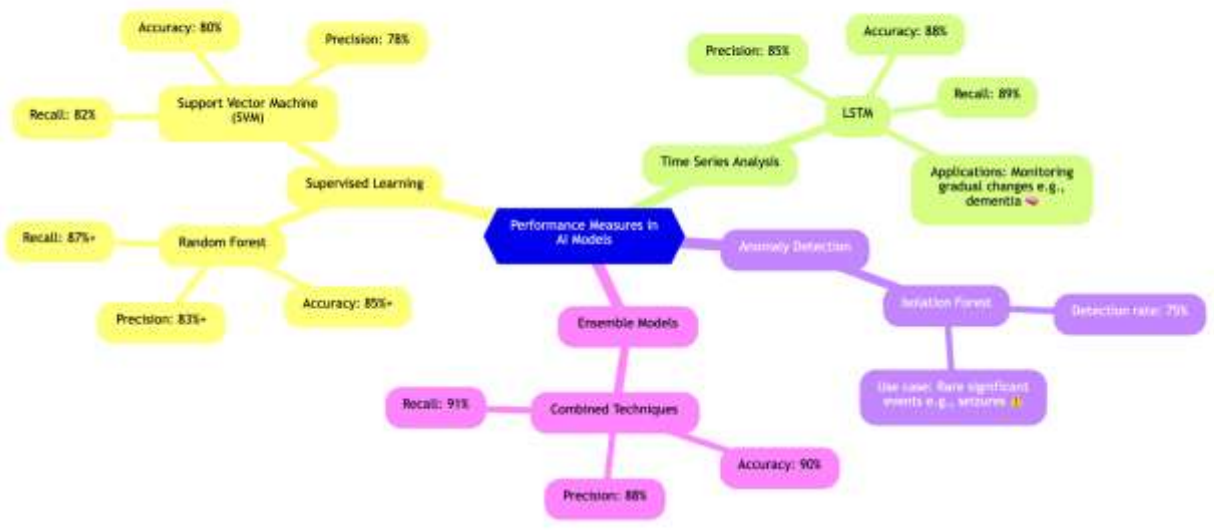



**(Fig 3. Heart Rate Variability vs. Anxiety Levels)**




**(Fig 4. Correlation Between Barking Frequency and Predicted Stress Levels)**

In addition to that, they also take into account the proxy measures of the neural condition of the subjects in addition to the behavior patterns. This enables a much clearer explanation of the neurological condition of the dog. Illustration of this semantic duality is how heart rate variability HRV is associated with anxiety and also some treated neurologic diseases [9]. Low HRV is associated with extreme anxiety level readings whereas reduced HRV will be 40 msec standard deviation and below for example. It is more efficient to employ feature fusion, a technique that combines barking features, motion patterns, and heart rate variability HRV, and so forth, as compared to any one of the features due to its advantage in improving accuracy. This part suggests that it is better to use a combination of several measures to understand the behavior and the neural condition of dogs.




**(Fig 3. Performance Measures in AI Models)**

Thanks to the incorporation of multimodal data, the system is more capable of identifying stress and neural disorders as compared to approaches that rely on single metrics only [19].

In aspects other than direct assessment of brain function, it appears that behavioral proxies like barking and motion patterns have an impressive potential in neural health assessment.

The evidence that presented data can be effectively learned by machines suggests that the previously impossible, early diagnosis of stress, anxiety, and cognitive problems in dogs can be realized through the use of readily available features.

The 3d representation of a virtual canine pet which has activities such as barking and barking imitation at the same time contains active activities that encompass very high levels of barking abounding ape noise. Forecast: More tension levels than what is manageable: Environmental enrichment – stress management approaches. Conclusion: Environmental enrichment – stress management approaches. These accomplishments speak to the possibility of implementation of the above intervention strategy to control emotional response in healthy dogs with the existing interventions – controlled in a manner that is non-intrusive to the dogs – that would be mostly advancements in veterinary and wearable technology.

## Discussion

The results obtained from this simulation strongly indicate the potential towards developing machine learning models that can predict the neural and emotional states of dogs based on the analysis of multimodal behavior data, for instance, increasing the rate of vocalization and the degree of motion which can be regarded as a behavior of stress while prolonged periods of low blood pressure variation can be linked to high levels of anxiety. This reinforces the hypothesis that such behavioral proxies can be advanced by machine learning techniques to assess the neural well-being of the subject.

In addition, the ability to make use of the time-series data to ascertain long-term patterns, for example; subtle decline in cognitive functions over time suggests the possibility of monitoring the health status of dogs in a longitudinal manner. The results also support the claim that the framework has the potential to provide stress such as anxiety and even some neurodegenerative diseases related early warning signs [7]. This thereby improves the possibility of development of pet wearables care technologies and intra cranial imaging technologies.

The freshness of AI incorporation is the machine learning aspect that focuses on more than just the physical characteristics of animals but also their psychological and emotional health. This is a huge improvement in the understanding and the keeping of the pet health status. The all-encompassing technique adds motion, sound, and other physiological features so that a complete picture of a dog's health is created [15]. This approach makes it possible to outperform the single-metric-based systems by utilizing a number of metrics.

The framework is also scalable and adaptable in that it can be modified for other animals or altered to fit existing wearable equipment. Such aspects of the framework make it useful in various fields in veterinary medicine. In addition, the system supports the control of the animal's health when there are signs of stress or problems with the nervous system. Such early recognition helps to provide appropriate treatment on time, which improves the healing of the patients as well as their general well-being. Such an elaborate account proves that the framework can completely change the monitoring of animal health.

The study appreciates certain limitations and difficulties that interfere with the efficiency of the framework and proposes ways of overcoming them. One of the main issues is the use of proxy measures where behavioral and physiological measures are used instead of directly measuring the neural variable of interest. These proxies do allow empirical association to be made between certain behaviors and the underlying neurological condition, however, they are not adequate in describing all natures of the neural state which calls for more specialized research work in those fields.

Additionally, the predicaments of correlating data come in, as there are few detailed subsidiary sources on dogs and how they behave as well as their brain function. This deficit hinders the training and testing performance of such machine learning algorithms as deep learning where real data is required, and painstaking simulations or modeling may not come close to the actual operation. Moreover, the translation of the technology into practice is hindered by the soft technology limitation of the wearable devices for non-stop data retrieval. Such devices are often latched onto individuals who are to be monitored with an external source of interference like noise or even the subject himself, making it difficult to collect the data in real time and interpret it correctly.

In order to overcome the observed obstacles as well as to improve the benefits of the suggested framework, a number of future directions are proposed. It is important to put more emphasis on empirical validation and conduct field studies that correlate behavioral proxies to neural health status utilizing primary data from veterinary clinics and research centers [5]. This will enhance the adequacy of the framework greatly. Another area of importance is the focus on developing more sophisticated sensors. Study the possibilities of combining non-invasive EEG or brain wave sensors with wearable devices such that brain activities can be ascertained directly, thus eliminating behavioral proxies to neural aspects [16]. Optimized data collection strategies are also very key, such that there is a need to partner with pet health organizations and centers to source vast, clean, and high-quality data relevant for training and validation of the models. Lastly, personalized models with respect to breeds, age, and lifestyle will improve the precision of the framework [17]. Such granular representation of profiles can greatly enhance the accuracy of the model's predictions, hence making the framework more flexible and accurate in the assessment of dog health. These actions will help in the development of a more sophisticated and integrative system in animal health management.

**Future Work**

This section of the inquiry further attempts to put forward some suggestions on how a dog's mental condition can be explored and forecasted given the behavioral and physiological information that can be treated as secondary signs of internal conditions. The fundamental issue in this area is raising the level of the parameters from just estimates to real measurements of dogs' brain activities. This, however, presents a serious difficulty in how to develop or incorporate existing means that can assess or measure the dog's brainwave activities while the dog is awake and engaged in activities. For example, using small EEG devices or even laser technology would involve carrying out in vivo imaging of the brain that will help improve these models and make them more precise.

Later portions of this framework will be reinforced with support from veterinarians and experts in animal ethology. This involvement in the veterinary work will be beneficial in:

1. Following protocols for obtaining de-identified health records to create and validate machine learning models.
2. Improving the quality of the databases used for supervised learning by employing domain experts in the collection of such data.
3. Identifying biomarkers, if any, for specific pathological conditions affecting the nervous system.

As a means of ascertaining the efficacy of the framework, it is essential that early investigations are planned in due course on a small scale in a controlled setting utilizing wearable prototypes. Such studies ought to emphasize on:

Recording of behavioral parameters and physiological data in real time.

Assessing the ability of the framework to predict actual veterinary diagnosis.

Evaluating the Applicability of the Framework in Various Breeds/Age/Lifestyles.

Although this study deals primarily with dogs, the structure can be extended to other pets, for example, cats, horses, and perhaps even some exotic animals. Each species has its own peculiar behavioral and physiological features, which require different methods. Adaptation of the framework to incorporate other creatures broadens its use and relevance in the veterinary profession.

Other enhancements that can be made include the integration of additional parameters such as temperature, air quality, and ambient noise into the model, which increases the ability to dynamically assess situational stressors and anxieties [12]. For instance, excessive background noises such as barking may trigger aggression in the subject, while poor air quality will make the subject inhale and exhale out air erratically. Environmental conditions will be combined with more behavioral and physiological measures, apparently creating a more useful control health system for the animals.

In further studies, ethical considerations should also be made in the future of wearable devices for pets. In addition, there is an urgent need to conduct more technology focus on making the devices low cost for pet owners and veterinary practitioners to improve chances of adoption of the technology.

Further elaboration of the framework should include the development of health profiles tailored to each dog. This can be achieved by adding information such as breed, age, lifestyle and past medical records and thereby enabling the system to give tailored advice and recommendations making it better and more useful.

As such issues are tackled, the suggest research will further develop from mere hypothesis to a viable solution for application in monitoring neural health in dogs. Such developments will open the possibilities of healthcare practices articulating the use of neuroscience and artificial intelligence within veterinary medicine for the provision of pet care that is more assertive and comprehensive.

**Conclusion**

The present research investigates one such area that remains neglected at this time, which is using artificial intelligence in monitoring the neural health of dogs. This would help in research and enhancing the emotional and neural care of canine companions in a completely different way. The authors come up with a framework that shows how stress, anxiety, and cognitive decline can be identified non-invasively by analyzing machine learning models with a collection of different types of behavioral and physiological data.

This study sets the stage for applications such as NeuroSense, an upcoming health management system that focuses on insights from a dog's neural wellbeing [8]. This data indicates how AI can change the veterinary sector for the better, particularly where diseases can be detected early on and preventive measures undertaken to ameliorate the condition and even the life of pets [15].

This study is primarily conceptual; however, the implications are very far-reaching. The advent of such instruments may considerably advance pet health care by connecting the disparate fields of neuroscience and animal welfare. Future growths that include real neural data and wearable technology can assist in pet health monitoring that is integrated and customized for each individual pet [14].

How Innovation in Veterinary Medicine Enhances Patient Care and Quality of Life The present research highlights the importance of technology in promoting animal health services and paves the way for more developments in the fields of computer science, neuroscience, and veterinary medicine. With an emphasis on early diagnosis and individualized treatment, the future looks bright and healthy for our beloved pets.

**References**

1. Zamansky, Anna & Sinitca, Aleksandr & Linden, Dirk & Kaplun, Dmitry. (2021). Automatic Animal Behavior Analysis: Opportunities for Combining Knowledge Representation with Machine Learning. Procedia Computer Science. 186. 661-668. 10.1016/j.procs.2021.04.187.
2. Amir, S., Zamansky, A., van der Linden, D., 2017. K9-blyzer: Towards video-based automatic analysis of canine behavior, in: Proceedings of the Fourth International Conference on Animal-Computer Interaction, pp. 1–5.
3. Barnard, S., Calderara, S., Pistocchi, S., Cucchiara, R., Podaliri-Vulpiani, M., Messori, S., Ferri, N., 2016. Quick, accurate, smart: 3d computervision technology helps assessing confined animals' behaviour. PloS one 11, e0158748.
4. Bleuer-Elsner, S., Zamansky, A., Fux, A., Kaplun, D., Romanov, S., Sinitca, A., Masson, S., van der Linden, D., 2019. Computational analysisof movement patterns of dogs with adhd-like behavior. Animals 9, 1140.
5. Egnor, S.R., Branson, K., 2016. Computational analysis of behavior. Annual Review of Neuroscience 36, 217–236.
6. Hall, C., Roshier, A., 2016. Getting the measure of behavior. .. is seeing believing? interactions 23, 42–46
7. Kabra, M., Robie, A.A., Rivera-Alba, M., Branson, S., Branson, K., 2013. Jaaba: interactive machine learning for automatic annotation ofanimal behavior. Nature methods 10, 64.
8. Kaplun, D., Sinitca, A., Zamansky, A., Bleuer-Elsner, S., Plazner, M., Fux, A., van der Linden, D., 2019. Animal health informatics: towards ageneric framework for automatic behavior analysis, in: Proceedings of the 12th International Conference on Health Informatics (HEALTHINF2019).

9. Mathis, A., Mamidanna, P., Cury, K.M., Abe, T., Murthy, V.N., Mathis, M.W., Bethge, M., 2018. Deeplabcut: markerless pose estimation ofuser-defined body parts with deep learning. Nature neuroscience 21, 1281.
10. Mikl´osi, ´A., 2014. Dog behaviour, evolution, and cognition. oUp Oxford.
11. Nevatia, R., Hobbs, J., Bolles, B., 2004. An ontology for video event representation, in: 2004 Conference on Computer Vision and PatternRecognition Workshop, IEEE. pp. 119–119.
12. Ropert-Coudert, Y., Kato, A., Gr ´emillet, D., Crenner, F., 2012. Bio-logging: recording the ecophysiology and behaviour of animals movingfreely in their environment. Sensors for ecology: Towards integrated knowledge of ecosystems 1, 17–41.
13. Tillett, R., Onyango, C., Marchant, J., 1997. Using model-based image processing to track animal movements. Computers and electronics inagriculture 17, 249–261.
14. Zamansky, A., Sinitca, A.M., Kaplun, D.I., Plazner, M., Schork, I.G., Young, R.J., de Azevedo, C.S., 2019. Analysis of dogs' sleep patternsusing convolutional neural networks, in: International Conference on Artificial Neural Networks, Springer. pp. 472–483
15. Fazzari, Edoardo, et al. "Animal Behavior Analysis Methods Using Deep Learning: A Survey." arXiv preprint arXiv:2405.14002 (2024).
16. Zhang, Xiang, et al. "A survey on deep learning-based non-invasive brain signals: recent advances and new frontiers." Journal of neural engineering 18.3 (2021): 031002.
17. Zhang, Xiang, et al. "A survey on deep learning-based non-invasive brain signals: recent advances and new frontiers." Journal of neural engineering 18.3 (2021): 031002.
18. Owoeye, Kehinde. On computational models of animal movement behaviour. Diss. UCL (University College London), 2021.
19. Ali Alameer, Stephanie Buijs, Niamh O'Connell, Luke Dalton, Mona Larsen, Lene Pedersen, and Ilias Kyriazakis. 2022. Automated detection and quantification of contact behaviour in pigs using deep learning. biosystems engineering 224 (2022), 118–130.
20. Zoe Ashwood, Nicholas A Roy, Ji Hyun Bak, and Jonathan W Pillow. 2020. Inferring learning rules from animal decision-making. Advances in Neural Information Processing Systems 33 (2020), 3442–3453.
21. Shoubhik Chandan Banerjee, Khursheed Ahmad Khan, and Rati Sharma. 2023. Deep-worm-tracker: Deep learning methods for accurate detection and tracking for behavioral studies in C. elegans. Applied Animal Behaviour Science 266 (2023), 106024.